DECEMBER, 1961

Welding Journal

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OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

To users of submerged arc welding equipment

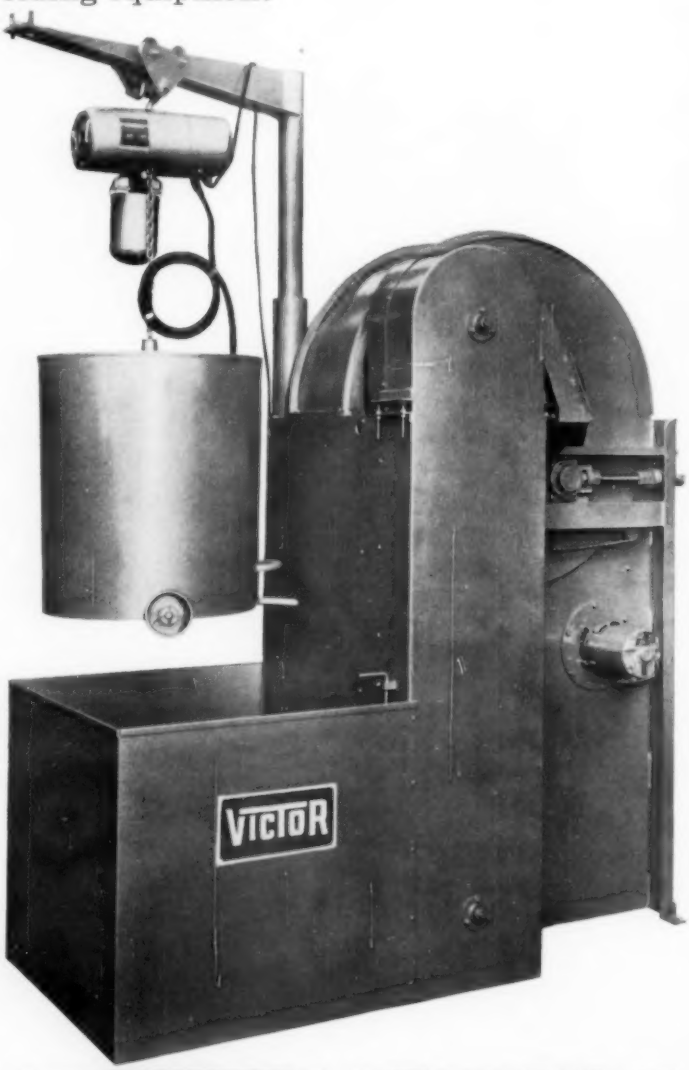
NOW! Reclaim both hardfacing and mild steel fluxes with VICTOR GRINDER

Completely automatic feed on Victor's new model flux grinder eliminates hand loading... removes tramp metal from and reclaims up to 80% of used flux . . . delivers as much as 1200 pounds hourly of re-ground flux, sized to factory specifications.

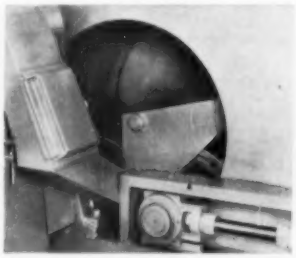
"Paid for itself in six months," says an owner of our previous model. Not bad, but you'll find this new, improved Model FG 200 even better. Here's why –

- Boom and electric ¼-ton hoist cut out hand lifting flux buckets.
- Self-loading hopper and conveyor eliminate manual feeding, assure a steadier and larger flow of flux.
- Three magnetic separators (2 more than before) trap and remove 90% or more of spatter and tramp metal.
- You get up to 1200 usable pounds hourly of either hardfacing or mild steel flux, so free of contaminants you can scarcely tell reclaimed from new.

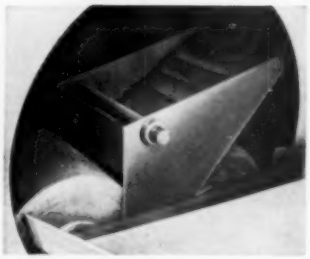
Why pay outsiders 4 to 5¢ a pound to regrind flux and lose half of it in the process, when a Victor improved flux grinder pays for itself? Order from your Victor dealer now. He's your one-stop source for welding and hardfacing supplies.



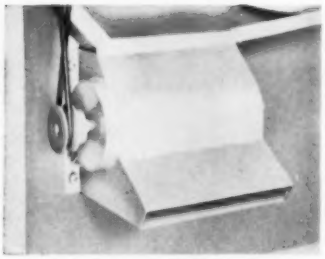
HOW VICTOR FREES FLUX AND TRAPS METALS



Primary magnetic separator removes most of loose metal as used flux feeds into crusher rolls. Hinged cover lifts for easy cleaning.



Here two hardfaced rollers crush fused flux, thus freeing all metal so second magnetic separator can pick it up as flux flows on.



Final magnetic separator at output spout catches last remaining metal particles. No wonder the Victor makes re-usable such a high percentage of fused and used flux.

VICTOR for hardfacing

VICTOR EQUIPMENT COMPANY

844 Folsom Street · San Francisco 7

3821 Santa Fe Avenue, Los Angeles 58 · 1145 E. 76th Street, Chicago 19

Mfrs. of roller and idler rebuilding machines; high pressure and large volume gas regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt and tungsten castings; straight-line & shape cutting machines

86-R

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Considerations on the Use of Gas Mixtures in Shielded Arc Welding with Consumable Electrodes, by L. Wolff and M. Komers ... 536-s
European Welding Research, by Gerard E. Claussen ... 539-s
The Hydraulic Bulge Test for Welded Aluminum Sheet, by I. B. Robinson, F. R. Collins and J. D. Dowd ... 540-s
The Welding of Titanium to Steel, by D. R. Mitchell and H. D. Kessler ... 546-s
Investigation of Residual Stresses by Use of Hydrogen Cracking, by Koichi Masubuchi and D. C. Martin ... 553-s
An Investigation of the Low-Temperature Impact Properties of Stainless-Steel Weldments, by H. W. Mishler and H. J. Nichols ... 564-s

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PRESS-TIME NEWS ...about ...People ...Welding ...Products

Midwest Welding Firm Completes 30 Years

Machinery and Welder Corp., Chicago, Ill., recently announced the completion of 30 years in the welding distributing field. At the same time, the firm appointed three AWS members as follows: R. L. Kohlbry—president, Wilbur Juergens—secretary and treasurer and G. F. Meyer—vice president.

Handy & Harman Moves Plant

The Providence plant of Handy & Harman, fabricators and refiners of precious metals, has moved to a new location at 845 Waterman Ave., East Providence, R. I. It was formerly at 425 Richmond St. in Providence.

Expanded and improved facilities will enable Handy & Harman to give greater service to its jewelry, silversmithing and industrial customers in the New England area. A complete stock of gold and silver products, brazing alloys and fluxes will be carried in the plant, which is also the New England collection station for precious metal refinings.

Eutectic Creates Division

Leonard C. Barr AWS, president of Eutectic Welding Alloys Corp., Flushing, N. Y., recently announced the organization of a new National Accounts Division. The new division will comprise of a group of highly qualified specialists who will devote their entire time and attention to the servicing and needs of large volume users of the company's products.

Four representatives for the new division have been designated. They are: Robert Whitney AWS who joined Eutectic in July 1955 and has been district manager in the south Manhattan area. He will serve national accounts in the greater New York metropolitan area.

John Ryan who will serve the greater Detroit and southeastern Michigan area.

Robert A. Wright AWS, who will serve accounts in the greater St. Louis area including portions of Illinois and Missouri.

Norman Day, who will cover the national accounts in the Southern California area.

New Application for Brazing Torches

Using standard spray-type brazing equipment and a new nickel-base hard-surfacing powder, items such as glass molds may be easily repaired at low cost according to the Wall Colmonoy Corp., Detroit, Mich.

The new powder (identified as Colmonoy 21) is recommended for repair of nicks, cracks or chips in mold edges, match lines and other critical mold surfaces. As deposited, it produces a consistent and

uniform hardness of approximately 28 on the Rockwell C scale. No hard spots are developed in the overlay. All overlay areas are readily filed for easy finishing to size, shape and desired smoothness.

Airco Names Distributor in Washington, D. C.

The Air Reduction Sales Co., New York, N. Y., recently announced the appointment of District Oxygen Co., Inc., of Brentwood, Md., as its exclusive distributor in the Washington, D. C. metropolitan area.

A major supplier and service agency to local industry, District Oxygen does a yearly volume of approximately a half-million dollars and employs 18 persons.

NAMED BY EUTECTIC

Robert Whitney

R. A. Wright

Model PKRC-500

NEW HOBART *Multi-wire* RECTIFIER HANDLES ALL SEMI-AUTOMATIC WELDING PROCESSES

. . . Years ahead in concept and design, the Multi-Wire Rectifier offers exceptional cost cutting advantages in one complete package. It feeds wire automatically to weld carbon steel, stainless, aluminum and many other non-ferrous alloys. Easily interchangeable components permit the use of these six different processes: Micro-Wire, MIG-CO_2, FABCO, MIG-ARGON, SUBMERGED ARC, OPEN ARC. Ask for complete details.

Hobart Brothers Company, Box WJ121, Troy, Ohio

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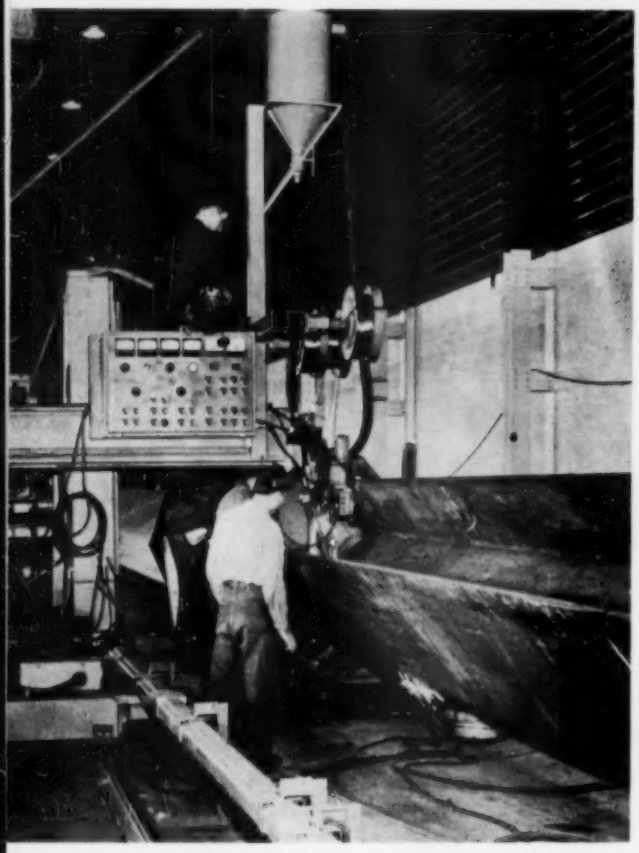
WELDING ZONES



Automatic tandem submerged-arc welding machine reduced welding time on new structural steel bridge components by 80%
(Courtesy R. C. Mahon Co.)

All-welded $1^{5}/_{32}$ in. steel-plate propylene storage and feed vessel was designed to operate at a pressure of 300 psi and a temperature of 250° F (Courtesy Bethlehem Steel Co.)

One of three fabricated $^{1}/_{2}$ in. thick wrought iron plate pump suction manifolds which has been in service for a new sewage plant and providing suction for variable speed pumps (Courtesy A. M. Byers Co.)

Demolition of the old Cleveland Press Building in Cleveland, Ohio, was expedited by the use of cutting equipment that provided automatic ignition and proper balance for one hand operation (Courtesy Harris Calorific Co.)

Not to be overlooked

Oerlikon welding electrodes are manufactured in:

	Switzerland	
Argentina	Germany	Philippines
Austria	Gt. Britain	Spain
Chile	Greece	Sweden
Colombia	India	Turkey
Finland	Italy	USA
France	Japan	
	Mexico	
	Pakistan	
	Peru	

D-M

Welding Electrode Division, Oerlikon Machine Tool Works Buehrle & Co, Zurich 50/Switzerland

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

BELGIUM

The magazine of the Belgian Welding Institute, *Revue De La Soudure* for the second quarter of 1961, contains the following articles:

- The electrogas process is marketed by a Belgian firm that supplies water cooled mold plates with side entry tubes for CO_2. The arc is maintained between a cored electrode and a bath of molten metal held by the mold plates between the two vertical steel plates to be joined. A speed of 3 ipm can be maintained in welding $^3/_4$-in. plates.
- Belgian Standard NBN 564 on covered electrodes describes tests for deposition rate, tensile strength and hardness of fillet welds, among others. It is a new publication of the Belgian Standards Institution and was written by the Belgian Welding Institute.
- Comparison of the Charpy with the drop weight test on the basis of percentage crystallinity of fractures showed that there was little difference in results. Fracture transition temperature in the Charpy test was constant for notch radii below 0.010 in., which made it appear that the extreme sharpness of the crack in the drop weight test did not further raise the transition temperature.
- The principal theoretical fields in brazing, namely: oxidation, diffusion, slags and electrochemical corrosion, are reviewed.

EAST GERMANY

Schweisstechnik Berlin for May 1961 contains the following articles:

- The fatigue strength of mild steel specimens simulating a bridge floor was determined. The specimens consisted of a floor plate with a hollow rib stiffener and a transverse plate stiffener. By changing from an interrupted rib to a continuous rib through the transverse stiffener, the fatigue strength was raised from 21,000 to 28,000 psi. Fillet welding the stiffener connection lowered the fatigue strength to 12,000 psi.
- In a discussion of welded railway bridges, fatigue tests are reported of girders consisting of two-piece flanges. The web plate is straddled by the two pieces and is welded to them from the outside surface of the girder by a single pass of submerged arc. The fatigue strength of the girders with two-piece flanges was 33,000–36,000 psi, compared with 43,000 for the usual girder with one-piece flange.
- An impulse condenser resistance welding unit differs from the usual condenser machine in discharging the condenser through an impulse generator rather than directly across the wires to be welded. Units of the impulse type are manufactured in West Germany and Russia.
- Alloy-containing submerged-arc flux is made by bonding 20% of ferrochromium to a mixture of MgO, Al_2O_3 and CaF_2 with sodium silicate. The highest chromium recovery and best bead appearance were secured by drying the flux at 840 to 1110° F. Higher temperatures oxidized chromium.

ITALY

The journal of the *Italian Welding Institute* for January-February 1961 discusses low-temperature tensile tests by the Institute's vice president on unwelded and welded steel specimens containing notches. The presence of a weld had no significant effect on the decrease in strength of the specimen as the temperature was lowered. This issue also contained a review of papers and reports presented at the Third International Congress on Non-Destructive Testing in Tokyo, March 1960.

NETHERLANDS

The May 1961 issue of *Lastechniek* contains a series of short articles on the "well-made weld." Of particular interest is a detailed description of joint types and sequence in welded oil storage tanks at Europoort. Another author found low hydrogen electrodes preferable to rutile types for welding galvanized steel. The welds were coated with a protective material consisting of zinc powder with plastic binder which withstood seven months at 100% relative humidity, 95° F without rusting.

POLAND

The March 1961 issue of the Polish welding magazines contains detailed descriptions of a pedal spot welding unit, 60 kva, a synchronous ignition controller for spot welding, water-to-carbide acetylene generators, and an arc-welding transformer for the range 30 to 130 amp. The April issue describes the building up of crane wheels by submerged-arc welding with a bonded flux made in the Polish Welding Institute. The deposit contained 0.28 Cr, 1.04 Mn, 1.35 Si, 1.04 Cr and reached 379 Brinell.

SWEDEN

Svetsen for March 1961 discusses the welding properties of a high-tensile boiler steel containing 0.18 C, 0.80 Mn, 0.30 Si, 1.05 Cr, 1.07 Ni, 0.25 Mo, 0.02 Al. A hardness survey of an IIW specimen consisting of a surface bead on a plate $3^1/_4$ in. thick showed a maximum hardness of 380 Vickers, compared with 180 for base metal when welded with a $^5/_{32}$ in. low hydrogen electrode at 170 amp. The specimen was 6 × 8 in. In tandem-electrode submerged arc welds made at 4000 amp., 7 ipm, the maximum hardness was 255. Preheating to 300° F was recommended for manual and automatic welding.

A comparison of ductility in the longitudinal and transverse directions of a 160,000 psi steel plate $1^1/_2$ in. thick, based on MIT tests, showed that a finish rolling temperature of 1330° F did not provide as high transverse ductility as a finishing temperature of 1650° F. Heating 24 hr at 2300° F reduced the average length of inclusions but coarsened the grain size.

Fatigue tests on steel $^5/_8$-in. thick containing 0.13 C, 1.49 Mn, 0.25 Si are described in the May 1961 issue of *Svetsen*. The axial stress pulsating tension fatigue limits at 2 million cycles were:

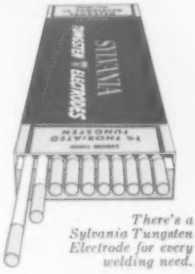
Unwelded, ground surface, psi	50,000
Unwelded, mill scale, psi	43,000
Machined butt joint, psi	41,000
Unwelded, sand blasted, psi	38,000
Fillet weld, not machined, psi	36,000
Unwelded, hot galvanized, psi	34,000
Machined fillet weld, psi	33,000
Butt joint without reverse weld, psi	28,000
Unmachined butt joint, psi	27,000

DR. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

adds pot of gold to piping "rainbows"

One way to profit from complex piping designs for petrochemical plants is to bank on the efficiency of Tungsten Inert Gas Welding. Whether it's piping, railroad cars, bridges or hardware for outer space, you'll find TIG welding means many benefits. Particularly if you select Sylvania Tungsten Electrodes.

Sylvania offers the most complete line of top-quality Tungsten Electrodes: Puretung®, Zirtung®, 1% Thoriated, 2% Thoriated. Each comes in the preferred finish—cleaned or ground, and color-coded to save you time and prevent costly errors. Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.



There's a Sylvania Tungsten Electrode for every welding need.

SYLVANIA

SUBSIDIARY OF

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

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USSR

Svarachnoe Proizvodstvo for April 1961 contains the following articles:

- A detailed study was made of the performance of a 150 kva flash welding unit with a fusion time of 12 sec. As machine resistance was increased from 0.078 to 0.355 ohm, thermal efficiency fell from 67 to 60%, effective current fell from 2245 to 1460 amp and defective welds became more frequent.
- Porosity in gas metal-arc welds in aluminum is due principally to moisture on the surface of wire and sheet. Pickling for 15 min in a bath at 86° F containing 25 ml orthophosphoric acid, 0.01–0.03 gm $K_2Cr_2O_7$, 1000 ml water removes moisture, but must be repeated after 5 or 6 days.
- A unit for resistance spot welding concrete reinforcing steel is described.
- Vibro-arc surfacing of worn, case-hardened steel is accomplished with a wire electrode $^1/_{16}$ in. diam at 140–150 amp, 12 v, wire speed = 43 in/min. The shaft to be surfaced was $^7/_8$ in. diam, made 11 rpm while the electrode advanced $^1/_{16}$ in. each revolution. The flow of cooling water was 0.2 pint per minute.
- The characteristics of welding mild steel in salt water were investigated with continuous wire electrode 0.047 in. diam and a CO_2 flow of 35 cfh. As salt concentration increased from 0 to 41% at 200 amp the arc voltage increased from 37 to 42 and the melting rate increased 15%. Saltiness had little effect on underwater welding.
- To weld cast iron, with a minimum of penetration, two $^5/_{64}$ in. steel electrodes in tandem were deposited at 210 amp.
- A new covered electrode for welding nickel alloys had a covering based on the TiO_2-CaF_2-NaF system and was bonded with sodium silicate. Mn, Ti, and Al were added to the covering. The weld metal contained 0.03 C, 1.43 Mn, 0.85 Si, 0.33 Fe, 0.48 Ti, 0.010 S and could be bent 180°. The tensile strength was 71,000 to 74,000 psi.

Yugoslavia

The tenth anniversary issue of *Varilna Tehnika* features a review of East Germany work on alloy transfer from coating to weld and on weldability of rimmed steel.

West Germany

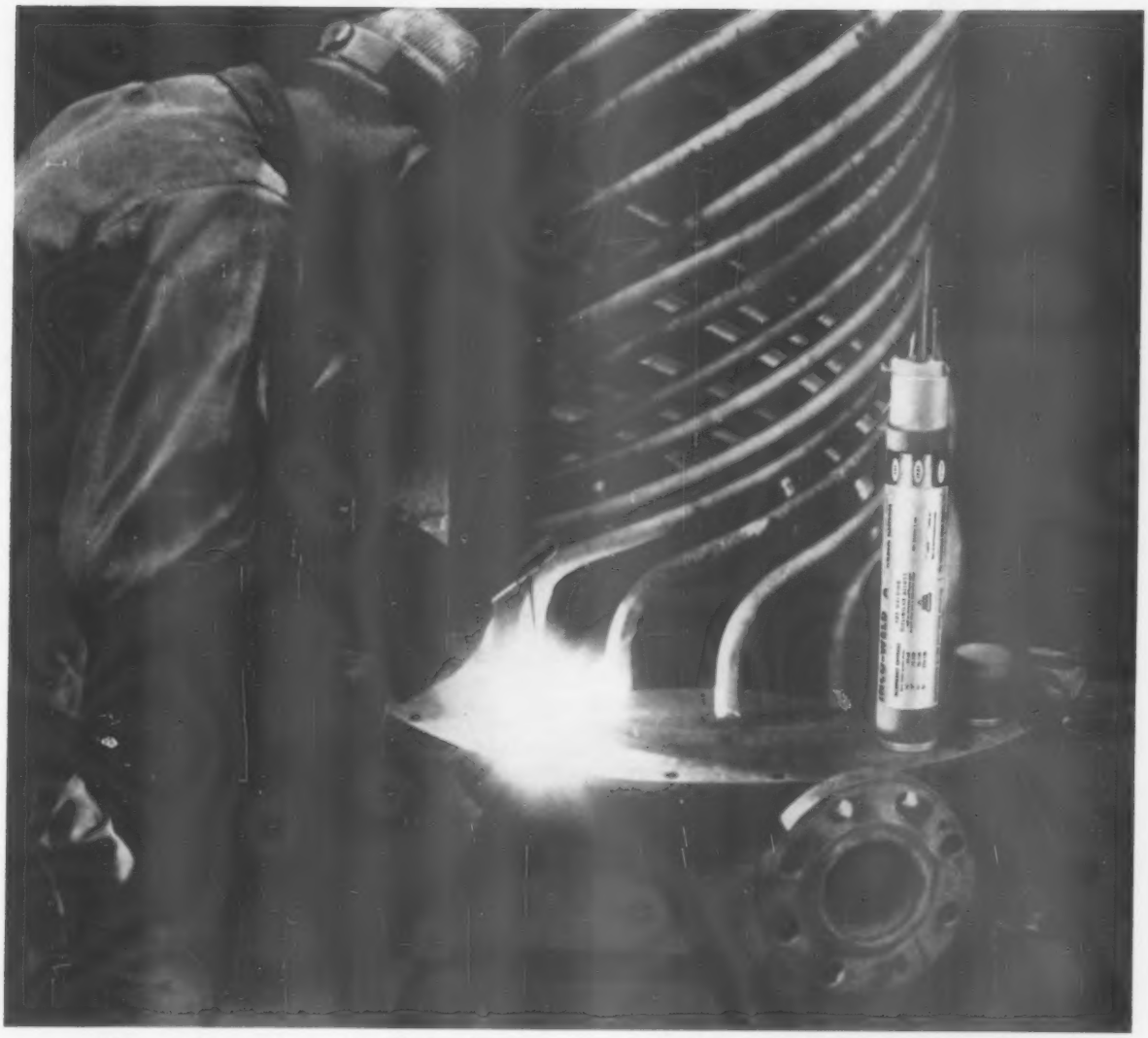
The July 1961 issue of *Schweissen und Schneiden* contains the following articles:

- The Mannheim welding laboratory of the German Welding Society with assistance from several firms and the Hannover Technical College conducted a detailed study of the strength of silver soldered joints in mild steel tubes and sheets. The solder contained 40% silver, the remainder being copper, zinc, and cadmium in equal parts. The flux contained boric acid, borates and fluorides. The joints were made manually with an oxyacetylene torch. It was necessary to file the mill scale from the joint area to secure freedom from porosity, which otherwise occurred when the operator found it necessary to overheat the joint to melt the excessive quantity of flux required. Filing in the direction of the joint was essential. Polishing or grinding was not effective. A tensile strength of 57,000 psi was achieved in butt joints in tubing 1 in. diam, 0.04- or 0.08-in. wall. A formula was derived for calculating the strength of inclined joints from joints at right angles to the axis of the tubing. Butt joints in sheets had a reversed bend fatigue strength of 23,500 psi. Silver soldered joints had low notch impact strength, 6 ft-lb compared with 50 ft-lb for the unsoldered steel. The electron microscope showed that any diffusion of solder into steel did not extend deeper than 1000 lattice parameters.
- A review of English and Japanese work on brittle fracture in large steel plates emphasizes the close connection between energy absorption-temperature curves for the large plates and for small sharp notch Charpy specimens.
- Austempering of welds in a high tensile steel, 200,000 psi tensile, did not improve the rotating bend fatigue strength of unnotched specimens compared with similar specimens that had been quenched and tempered. The tensile strength austempered (20 min at 1650° F, 60 min at 750° F) was 178,000 psi compared with 196,000 psi for quench and temper. The unnotched fatigue strength was 85,000 psi for both. The notched fatigue strength was 61,000 psi for austemper and 49,000 psi for quench and temper. In general, austempering was found to lack the advantages for welded joints that it had for unwelded steel.
- Formulas are given for designing welded supports for boilers.
- German Standard DIN 8565 was issued in May. It covers metal spraying of steel structures with zinc or aluminum for rust prevention.

The April 1961 issue of *Archiv fur das Eisenhuttenwesen* describes research on the effect of phosphorus on the notch impact value of mild steel weld metal. Lowering the phosphorus content from 0.038 to 0.015% doubled the notch impact value in one series of tests on submerged-arc weld metal. Addition of aluminum to refine the grain structure and raise the impact value of the weld was unsuccessful.

SPAIN

The Jarama River Aqueduct was built and erected by the Sociedad Metalurgica Ouro Felguera Co. to be used by Compania del Canal de Isabel II, Madrid
(Courtesy Instituto de la Soldadura)



Weldor at Thermal Research and Engineering Corp., Conshohocken, Pa. uses INCO-WELD "A" Electrode to join INCONEL alloy 600 tubing to mild steel. The completed unit will serve in a gas-fired heat-exchanger.

Why INCO-WELD® "A" Electrode can be used for 97% of all dissimilar alloy welding

With INCO-WELD* "A" Electrode you can make strong, sound, ductile welds between almost all weldable dissimilar alloy combinations. And the deposits will match or better the heat and corrosion resistance of the base materials.

The good high and low temperature properties of INCO-WELD "A" Electrode make it useful for joining materials that have to withstand temperatures as low as −300° F and as high as 2000° F.

Some typical examples of dissimilar alloys that can be welded satisfactorily with INCO-WELD "A" Electrode are:

Steel to	304 Stainless 309 Stainless 316 Stainless 430 Stainless
MONEL* alloy 400 to	304 Stainless 316 Stainless
INCONEL* alloy 600 to	Steel 304 Stainless 316 Stainless
INCOLOY* alloy 800 to	Steel 304 Stainless 316 Stainless

INCO-WELD "A" Electrode is easy to use. There's no need for special equipment or training. It has good operability in all positions and an exceptionally stable arc. Work seldom needs pre- or post-heat. INCO-WELD "A" Electrode is readily available in standard diameters in 5 lb. containers.

If you'd like more information on INCO-WELD "A" Electrode, write for our free booklet, "Now You Can Weld Dissimilar Alloys Easily."

*Registered Trademarks of The International Nickel Co., Inc.

HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17 INCO **West Virginia**

INCO WELDING PRODUCTS

ELECTRODES · WIRES · FLUXES

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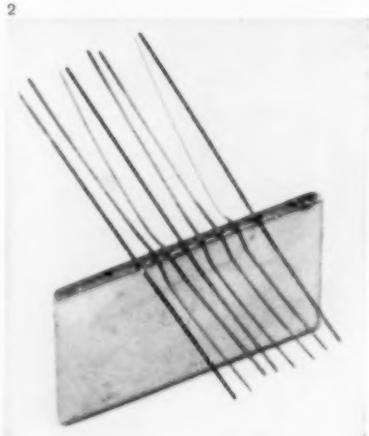
"Impossible" welds

Welds that are impossible by any other technique are now routine with Hamilton-Zeiss' high-energy density electron-beam welding. Hamilton-Zeiss equipment offers you unique performance combined with flexibility, reliability and repeatability / Difficult materials, unequal dimensions and deep penetrations present problems that only Hamilton-Zeiss welding equipment can solve with its high-energy density and precision electron-beam focusing by the exclusive Zeiss magnetic lens system. The Hamilton-Zeiss weld, created in a vacuum, offers these significant advantages: virtual elimination of contamination, close control of penetration, low thermal distortion and close dimensional control. Exhaustive tests demonstrate conclusively that welds produced by the Hamilton-Zeiss method are as strong as the original materials. Supporting metallurgical data are available for your inspection / For full information call Hamilton-Electrona, Inc., exclusive marketing agent for Hamilton-Zeiss equipment in the United States and Canada.

1

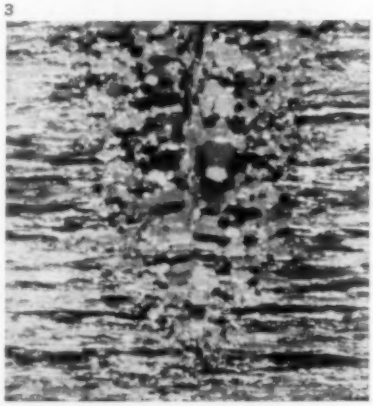
1 / Penetration study of one-inch thick Type 302 stainless steel reveals an amazing depth-to-width ratio. High-energy density and sharp focusing produce this unique weld with no reduction in the original strength of the material.

2



2 / Copper ribbon wires (0.002" x 0.010") welded to the edge of a nickel-plated ceramic substrate. This is just one demonstration of the ability of Hamilton-Zeiss equipment to weld dissimilar materials. Because of the unique design of the Hamilton-Zeiss equipment, electrons travel at approximately 110,000 miles/second to the work piece.

3



3 / Study of weld on 0.100" tungsten shows minimum grain growth and no evidence of contamination. The high-energy density beam minimizes grain growth because welding time is extremely short and heat is applied to an exceptionally small zone. Contaminants are eliminated by welding in a high vacuum without filler; impurities are outgassed during the cycle.

HIGH-ENERGY DENSITY ELECTRON-BEAM WELDING BY HAMILTON-ELECTRONA, INC. / TIME-LIFE BUILDING, ROCKEFELLER CENTER NEW YORK 20, N.Y. / PHONE PLAZA 7-9548-9

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Under One Roof

The AWS recently moved its headquarters into the new and modern United Engineering Building on East 47th St. in New York City. Except to those who work there this may not seem particularly important, yet the fact that other technical societies are also housed there provides material for interesting speculation.

One of industry's frustrations is the incompatibility of our separate codes and specifications; one of its disappointments is the lack of basic fundamental knowledge, and one of its greatest needs is the understanding and cooperation among those who can solve these problems.

The Code Writing Committees and Research Teams of our different societies represent highly diversified groups with different outlooks, different aims and different approaches to their problems, but they are sincere and dedicated people who have proved that joint committees can work out solutions to mutual problems and efficiently manage research and investigations in areas of mutual concern.

The fact that these groups are now under the same roof almost guarantees that they can meet together more easily and more frequently and get to know each other better. When this happens, mutual problems will disappear. We may find that this "fringe benefit" is the greatest contribution of the United Engineering Building to engineering.

Within the shadow of the United Engineering Building is the United Nations Building. This also houses diversified groups with incompatible ideas and different approaches to mutual problems. We should not belittle their problems by comparison with our own, yet the solutions, because they are problems of people, are the same. Within the United Nations Building are also sincere and dedicated men. Is there hope that it can promote the same understanding and mutual trust, and should we not show them the way?

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BRAZING ALLOY REFERENCE CHART

SILVALOY BRAZING ALLOYS								
SILVALOY	NOMINAL COMPOSITIONS					Solidus °F	Liquidus °F	Density troy oz /cu in
	Ag	Cu	Zn	Cd	Other			
5	5	88.75	0	0	P=6.25	1190	1300	4.37
15	15	80	0	0	P=5	1190	1300	4.45
35	35	26	21	18		1125	1295	4.90
45	45	15	16	24		1125	1145	4.92
50	50	15.5	16.5	18		1160	1175	5.00
503	50	15.5	15.5	16	Ni=3	1170	1270	5.00
355	56	22	17	0	Sn=5	1145	1205	5.00
I-401	5	0	16.6	78.4		480	600	4.53
377	5	0	0	95		640	740	4.60
A-4	9	53	38	0		1410	1565	4.50
20	20	45	30	5		1140	1500	4.64
A-11	20	45	35	0		1315	1500	4.68
A-79	25	52.5	22.5	0		1250	1575	4.71
A-13	30	38	32	0		1370	1410	4.67
250	40	30	28	0	Ni=2	1220	1435	4.76
254	40	30	25	0	Ni=5	1220	1580	4.72
A-14	40	36	24	0		1235	1415	4.80
105	45	30	12	0	Mn=13	1298	1298	4.76
A-18	45	30	25	0		1225	1370	4.82
A-25	50	34	16	0		1250	1425	4.99
54	54	40	5	0	Ni=1	1340	1575	5.06
A-33	60	25	15	0		1245	1325	5.02
60	60	30	0	0	Sn=10	1115	1325	5.23
T-50	62.5	32.5	0	0	Ni=5	1435	1590	5.19
Easy	65	20	15	0		1240	1325	5.06
Medium	70	20	10	0		1275	1360	5.14
301	72	28	0	0		1435	1435	5.24
AE-102	72	27.8	0	0	Li=.2	1410	1410	5.22
K-427	75	0	25	0		1300	1345	5.06
T-51	75	24.5	0	0	Ni=.5	1435	1475	5.30
Hard	75	22	3	0		1365	1450	5.28
T-52	77	21	0	0	Ni=2	1435	1525	5.32
A-49	80	16	4	0		1345	1490	5.29
AE-100	92.8	7.0	0	0	Li=0.2	1410	1610	5.46
S-475	95	0	0	0	Al=5	1550	1600	5.73
AT-601	97	0	0	0	Li=3	1115	1235	3.54
AT-600	98	0	0	0	Li=2	1290	1400	4.03

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	Au	Pd	Ag	Cu	Other			
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491		10	58	32		1520	1565	5.30
490		15	65	20		1565	1650	5.45
493		20	52	28		1615	1650	5.41
492		25	54	21		1650	1740	5.51
428		5	95			1780	1850	5.56
431		10	90			1835	1950	5.60
447		20	80			1960	2150	5.67
485		30	70			2120	2250	5.74
238	80			20		1630	1630	8.28
261	75		5	20		1625	1640	7.99
265	72				(Ni=22) (Cr=6)	1785	1835	7.48
242	37.5			62.5		1814	1859	5.90
260	35			65		1832	1870	5.80
243	35			62	Ni=3	1787	1886	5.81
255	82				Ni=18	1742	1742	8.41
129		60			Ni=40	2260	2260	5.58
440		20	75		Mn=5	1830	2050	5.56
441		33	64		Mn=3	2100	2190	5.70

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Girders being installed on third floor of Manhattan restaurant building to support a ten-floor parking garage above the restaurant level and to eliminate the need for structural columns which would project through the restaurant

Special Welding Techniques Minimize Stresses and Distortion in **Heavy Plate** Girders

for supporting a parking garage over a new restaurant owned and operated by a nationally known football and baseball fan

BY PHILIP DREIER AND CHARLES M. DICK, JR.

Special welding techniques to reduce distortion and balance internal stresses in large weldments were recently used to fabricate six heavy all-welded A-7 structural steel girders. Following fabrication, the girders were installed three stories up in a mid-Manhattan building spanning a new restaurant owned by the well-known Toots Shor. The function of the girders is to support the weight of a 10-story parking garage and eliminate structural columns from cutting through the restaurant space below.

The largest girder weighs 25 tons and is 46 ft long. It was designed to support a 580,000-lb total load. Because of this weight load, standard rolled beams of adequate strength were not available. The heavy plate girders had to be shop welded by a structural steel fabricator and erector.

Typical of the job were double-bevel butt welds joining 4- to 6-in. plates. Special welding techniques were needed to balance internal stresses. The completed girders were so thick that gamma irradiation from a radium source was the only practical method for nondestructive testing.

PHILIP DREIER is Chief Engineer for Dreier Structural Steel Co., Inc., Long Island City, N. Y.; CHARLES M. DICK, JR., is Murex Electrode Product Manager for Metal & Thermit Corp., Rahway, N. J.

Largest Girder Has 2-In. Thick Web

The girders were fabricated by welding as shown in Fig. 2 which illustrates the largest or the 25-ton girder. Measuring about 46 ft long, 2 ft 2

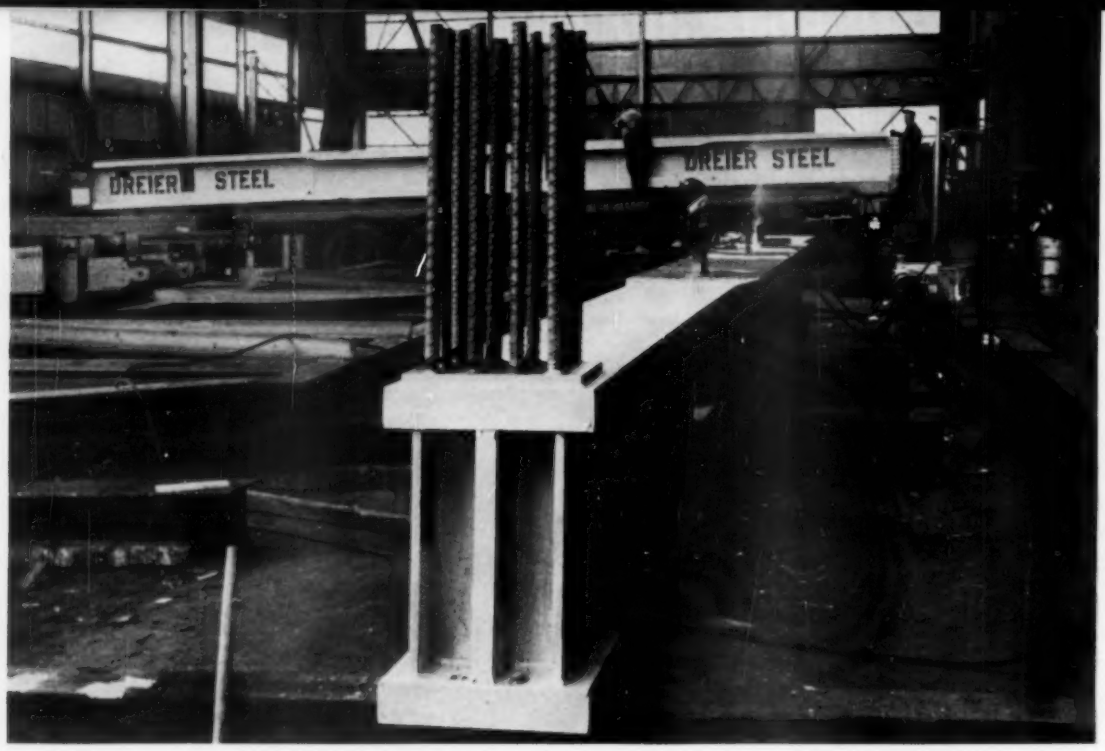


Fig. 1—Shop fabrication of six heavy all-welded plate girders involving special welding techniques. The largest girders weighed 25 tons and measured 46 ft long. Welding methods used were designed to balance internal stresses. Complete girders were so thick that gamma irradiation from a radium source was the only practical method for nondestructive testing

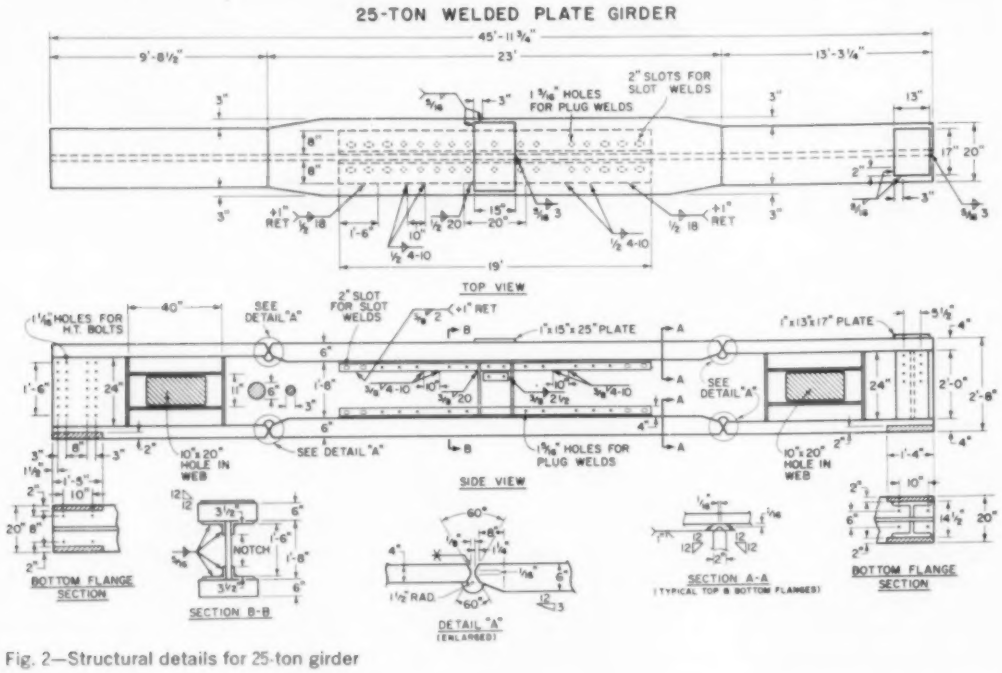


Fig. 2—Structural details for 25-ton girder

in. wide and 2 ft 8 in. high in gross dimensions, the girder's web plate is 2 in. thick. Flange plates are 4 in. thick at the ends and taper to a thickness of 6 in. about $10^1/_2$ ft in toward the center. A 1 in. vertical camber was built into the member.

Web and flanges were joined with 2-in. double-beveled "T" welds as shown in Section A-A of Fig. 2. Section B-B gives the details on welding the four longitudinal reinforcing angles to the web and flanges. The four angles, measuring 8 x 4 x 1 in., are 19 ft long. Intermittent fillet welds and plug welds join the angles to the girder. Twenty $1^5/_{16}$ in. plug welds and twelve 2-in. slot welds, filled solid, were used on the horizontal leg of the angle. Six-

teen 2 in. slots and 48 plug welds join the vertical angles to the girder's web.

Double 60-deg bevel butt welds join 4- and 6-in. plate to reinforce the central section of the girder as shown in detail "A."

Holes for air ducts and water pipes were cut by an oxyacetylene torch in the web section as shown in the drawing. Additional reinforcing plates were welded to reinforce these openings—Fig. 3.

Details on end sections of the 25-ton girder are also given in Fig. 2. After each girder was fabricated, structural reinforcing steel rods were tacked on and welded in a flat "T" joint to a 1-in. thick plate on the girder's end as shown in Fig. 4. These reinforcing rods are included in poured concrete columns supporting the upper stories of the parking garage.

Table 1 gives gross details on all six girders. The total load on each girder is one-half live load (varies as cars are moved in and out of the garage) and one-half dead load (includes weight of building above girder and girder's own weight).

Fig. 3—Welding operator joins reinforcing plates around hole in girder web. Hole is for air ducts and electrical cables

Fig. 4—Structural steel rods being welded to 1 in. thick plate at end of girder

Welding Procedure Balances Stress

To eliminate problems from distortion and weld cracking due to internal stresses in the large weldments, a standard step-by-step welding procedure was developed to balance internal stresses and relieve distortion. By using two welders on a team, each man put an equivalent pass on the girder on the opposite side and in the opposite direction from his partner, working from the center to the girder ends. The details of the welding sequence were as follows:

1. Flange plates were joined and butt welds finished before assembling the flanges to the web plate. Web and flange plates were then assembled and all stiffeners were welded except those going over the longitudinal reinforcing angles.

2. Stiffeners were welded to the web plate, starting at the center and working toward the ends (the unrestrained portion) to minimize distortion. One man was used on each side starting at the center of the girder, working toward opposite ends. This procedure tended to keep distortion and locked-up stresses to a minimum.

3. The web plate was next welded to flange plates with the girder lying flat, starting at the center and working out as described above. Then the remaining stiffeners were welded to the flange plates.

4. Butt welds were ground down flush with the web and flange plates where longitudinal angles were to be placed. All weld grinding was done in the longitudinal direction.

After assembling longitudinal angles and the remaining stiffeners on the girder, they were welded using the techniques described above.

Welding Details

The initial root passes of all bevel welds were made using low-hydrogen, iron powder $^{5}/_{32}$ or $^{3}/_{16}$ in. E7018 electrodes operating at 250 amp. All fill-in passes were made with heavily loaded, iron powder $^{1}/_{4}$-in. E6027 electrodes at about 450 amp ac. The E6027 iron powder electrodes were selected for their welding characteristics and high deposition rate of more than 17 lb per hour. The E7018 electrodes used on root passes develop 75,000–80,000 psi tensile strength and 65,000–70,000 yield strength with 30 to 35% elongation in 2 in. The fill-in E6027 electrodes

Table 1—All-Welded Plate Girder Specifications

	Total weight, tons	Overall girder dimensions— Length, ft	Width, in.	Depth, in.	Flange plate thickness, in.	Web plate thickness, in.	Maximum total load on each girder, including floor, lb
Girder 1	25	46	26	32	4–6	2	651,000
Girder 2	21	45	26	32	4–6	2	610,000
Girder 3	17	46	20	44	$3^{3}/_{4}$	$1^{1}/_{4}$	681,000
Girder 4	14	46	20	44	$2^{1}/_{2}$	$1^{1}/_{4}$	561,000
Girder 5	13	38	20	32	3–4	2	558,000
Girder 6	$7^{1}/_{2}$	33	18	32	2	1	454,000

Table 2—Electrode Test Results

Electrode Designation	Electrode Diameter, in.	Amp, ac-dc	Burn-off rate, ipm	Deposition, lb per hr
E-6024	1/4	350–425 ac-dc (either polarity)	(ac) 8.80–11.24	10.00–12.50
		350 dc (reverse preferred)	10.14	11.47
			(lb per hr)	
E-6027	1/4*	425–475 ac	22.40	17.31
E-6020	5/16	350–425 dc (straight polarity)	15.78–18.40	11.31–12.60
		375–450 ac	13.75–17.75	10.15–12.86
E-6020	3/8	500 dc (straight polarity)	21.81	16.22
		500 ac	20.55	14.92
E-6020	1/2	280 dc (straight polarity)	12.35	8.95
		330 ac	14.05	9.90

* Electrode finally selected for fill-in passes because of high deposition rate.

Fig. 5—Radium emission photographs of web-to-flange (top) and flange butt (bottom) welds for 25-ton girder

develop 62,000–67,000 psi tensile and 52,000–57,000 psi yield with 30 to 35% elongation in 2 in.

Selection of the proper electrodes for the job entailed laboratory and shop testing. Results of the testing, which sought the highest available electrode burn-off and deposition rates, are summarized in Table 2.

Initial root passes on bevel welds were back-chipped and cleaned after turning and prior to commencement of the initial weld on the reverse side. Double-bevel welds were made alternately from both sides with a maximum of 3 layers of weld metal deposited before turning. The maximum thickness of weld metal built up behind the advancing arc was kept to 1/8 in.

Starting points of all welds were preheated for a distance of 3 in. Plate 2 in. thick and under was heated to 350° F. Plate over 2 in. thick was heated to 450° F.

All tack welds were made with low hydrogen, iron powder E-7018 electrodes, as were all fillet welds. The 3/16 and 1/4 in. electrodes were preferred for fillet welds. Electrodes were kept in a holding oven at 250° F when not in use.

The various methods described above helped either to make weld metal, as deposited, free as possible from internal stresses or to balance whatever stresses remain. Also any possible distortion was corrected by working from the center out on opposite sides and on opposite directions on the girder.

The welding methods described here resulted in high-quality girders. This observation was backed up by radiographic nondestructive testing.

Radium Used for Nondestructive Tests

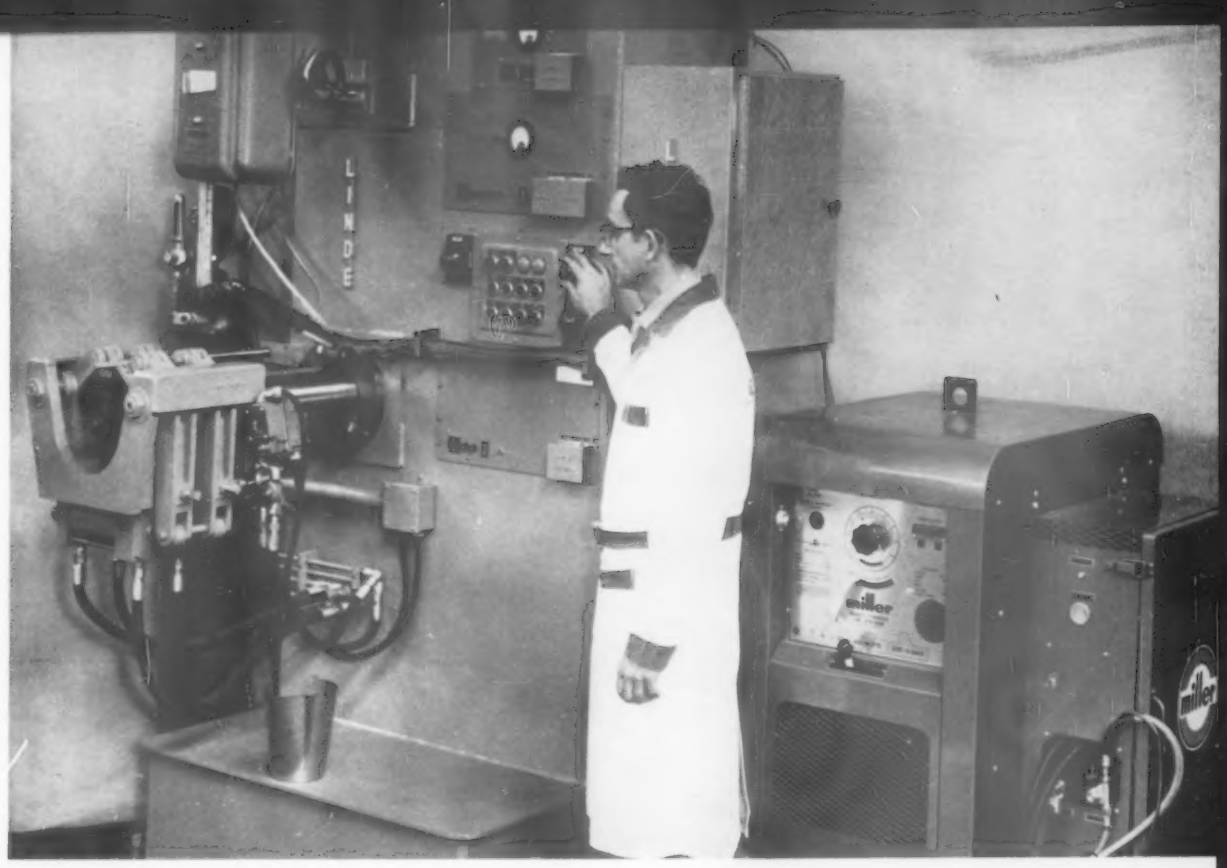
Due to the thickness of the weldments and the weight of the girders, portable X-ray machines would not develop enough voltage to produce penetrating X-radiation. The heavy girders could not be moved to a laboratory. However, by placing a 500-mg capsule of radium salts in an aluminum can on a 10-ft pole half way between the flanges (16 in. from the film), exposures of the 4 in. thick weldments were made in a little over 3 hr—Fig. 5.

A sampling of 1/6 of the large butt welds, taken at random, demonstrated the success of the welding method and no further inspection was deemed necessary.

Acknowledgment

The architect for the project is John Harold Barry, A.I.A.; the structural engineers are Seelye, Stevenson, Value & Knecht; and the general contractor is the H. R. H. Construction Corp. All are of Manhattan. The steel fabricator and erector is the Dreier Structural Steel Co., Inc., of Long Island City, New York.

Radiographic inspection of the weldments was carried out under the supervision of Seelye, Stevenson, Value and Knecht.



Longitudinal welding machine used on coffee maker

The requirements of precision welding, which goes far beyond automatic welding in its objectives, are outlined in

A Philosophy of **Tooling** for Inert Gas Welding

BY F. J. PILIA AND H. G. RATH

Introduction

Electric welding has developed rapidly since its beginning. The early 1940's saw the inert-gas welding processes come into being. These were adaptable to mechanized welding and, as a result, many attempts were made to design and build welding tooling that would replace the welding operator for mechanized or automatic operations. From 1950 to 1955, mechanized welding in this country improved to the point of so-called automatic welding. In automatic welding, parts are fed either manually or mechanically into a welding fixture, and the operator merely pushes a button to start the welding sequence —the parts are clamped, welded and ejected automatically. By and large, however, early applications of automatic welding were restricted to work of a relatively noncritical nature.

In the past few years another new form of welding has emerged and goes far beyond mere automatic welding in its objectives. This is precision welding. This paper is devoted to the philosophy that the successful design and construction of precision welding tooling—which is absolutely necessary for precision welding—demands the same painstaking attention to fundamentals as does the design and building of machine tools. While the ideal approach is emphasized, it is realized full well that compromises may be necessary in order to control costs.

Fundamentals

With modern precision welding tooling and ma-

F. J. PILIA and H. G. RATH are in Electric Welding Development, Linde Co., Div. of Union Carbide Corp., Newark, N. J.

Paper presented at the AWS National Fall Meeting held in Detroit, Mich., during Sept. 28 to Oct. 1, 1959.

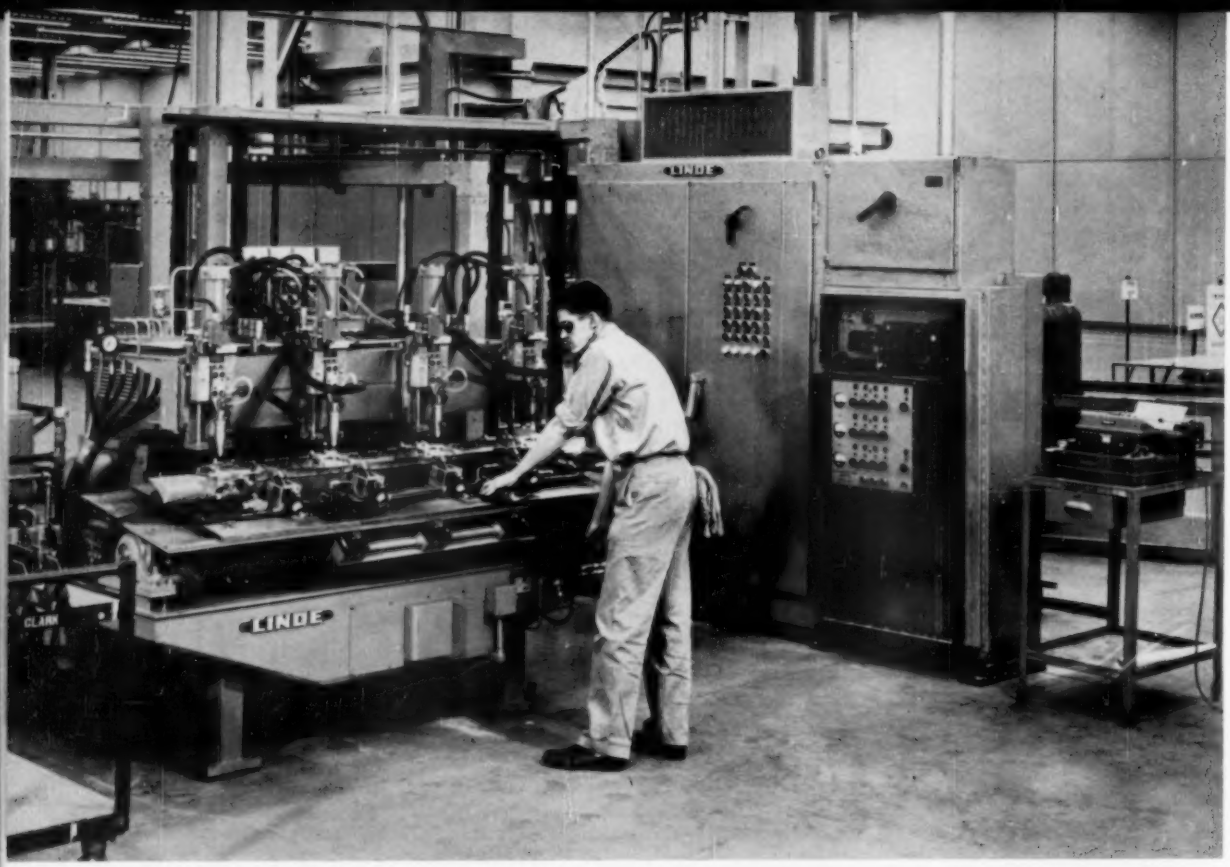


Fig. 1—Tape-controlled gas tungsten-arc spot welding machine for fabrication of missile fins

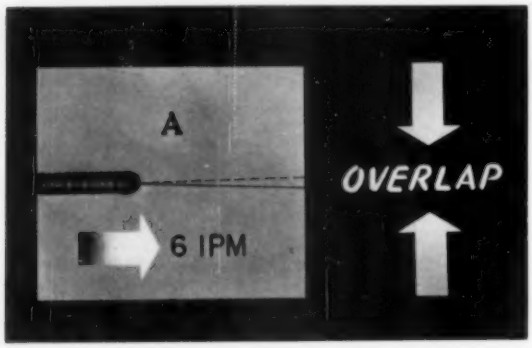


Fig. 2—Overlap at 6 ipm with oxyacetylene torch

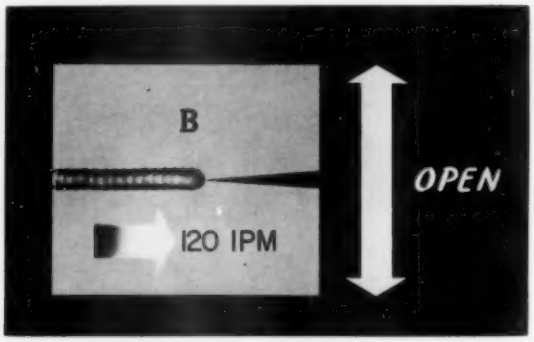


Fig. 3—Opening of sheets at 120 ipm with gas tungsten-arc welding

chines such as the tape-controlled tungsten-arc spot welding machine shown in Fig. 1, it is possible to make weldments to machine tool tolerances at high production rates, and to a degree of consistency, reliability and accuracy never before possible.

This particular machine is presently used to fabricate missile fins. It automatically makes 1900 high strength spot welds per hour, positioned accurately within 0.001 in. and in sequence to produce an undistorted, aerodynamically perfect contour in these parts.

A review of some of the fundamental principles learned early in welding is worthwhile. As shown in Fig. 2, if two pieces of a given material are laid out on a welding table with no restraint to hold them in place and if then welding is started with an oxyacetylene torch at speeds of about 6 ipm, these sheets would tend to overlap. With the same two sheets, Fig. 3 shows that when a weld is made with the gas metal-arc, tungsten-arc or submerged-arc processes at a speed of about 120 ipm, the sheets would tend to open.

At some speed between these two, there would be a critical speed at which no movement would occur as shown in Fig. 4. This critical speed varies depending upon the thermal conditions around a given

weld at the time that it is being made. It is influenced by material thickness, heat conductivity of the material, and heat sink in the fixture. If the critical speed for a particular weldment, is known, this information can be used to minimize the effect of such conditions as poor fitup by keeping the speed below the critical level and causing the seam to close as the weld progresses. In the case of crack sensitive materials, it may be desirable to stay slightly above the critical speed in order to avoid cracking, or other distortion problems. Obviously the minimum distortion will occur in any weldment when it is made at speeds as close to the critical speed as possible. However, the critical speed occurs at a quite definite point, and it is not always possible, in practice, to work exactly at the critical speed. Knowing the general area in which it occurs is usually sufficient for good shop practice.

The speed of welding has a very definite effect on the distribution of energy delivered to the part being welded. For example, in Fig. 5 is seen a thermal pattern plotted around an oxyacetylene weld where there is a very broad spread of heat from the welding zone into the sheet. In this weld probably 80% of the total energy input is lost to radiation and conduction into other parts around the weld, and only 20% of the energy is used to make the weld.

Figure 6 shows a high speed mechanized weld. Its thermal pattern is very narrow compared to that of the slower speed oxyacetylene weld. In this case energy losses might possibly amount to only 30% whereas 70% might be used in making the weld. It is the amount of waste energy, lost by radiation and other causes, that brings about the difficulty in making a weld. This goes into creating distortion and stresses which cause weld failure.

The electric arc is probably one of the most uniform sources of heat available. It is therefore true that, if there are uniform thermal conditions surrounding the edges of the sheets to be welded, the application of this uniform heat source will result in a uniform mechanized weld. However, control of the factors which affect thermal conditions in this area is a fairly complex problem; it involves surface alignment, fitup between the edges, relief groove or backing design, heat sink and several other variables as shown in Fig. 7.

A primary consideration is the maximum allowable gap between the edges of the sheet to be welded. Manual welding operators can sometimes weld gaps up to 100% of the sheet thickness. However, as portrayed in Fig. 8, mechanized welding is not as tolerant of gap as the manual operator. Years of experience have shown that the maximum gap which can be consistently welded in production by the tungsten arc welding process is 10% of the thinnest sheet in the joint. If the edges are beveled, this usually represents 10% of the nose or land thickness of the joint. The gas metal-arc process is more tolerant, and consistent results can be obtained

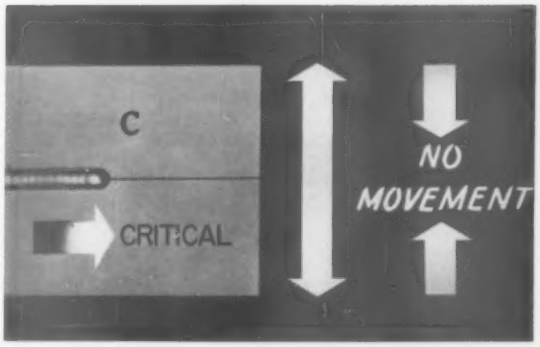


Fig. 4—Critical speed

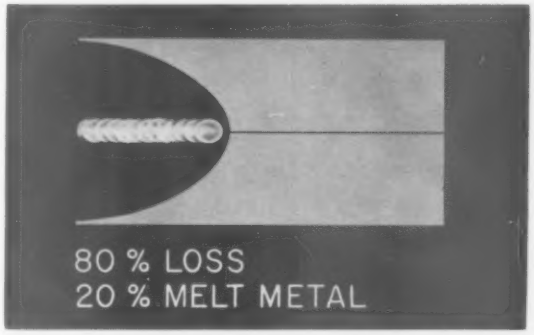


Fig. 5—Thermal pattern around oxyacetylene weld

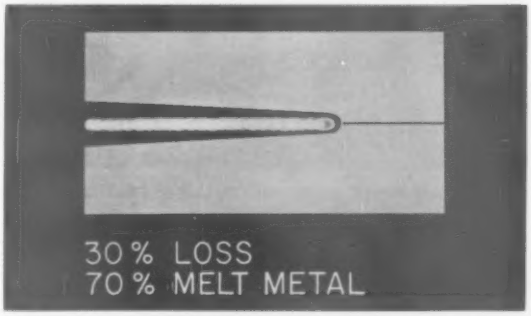


Fig. 6—Thermal pattern around high-speed mechanized welds

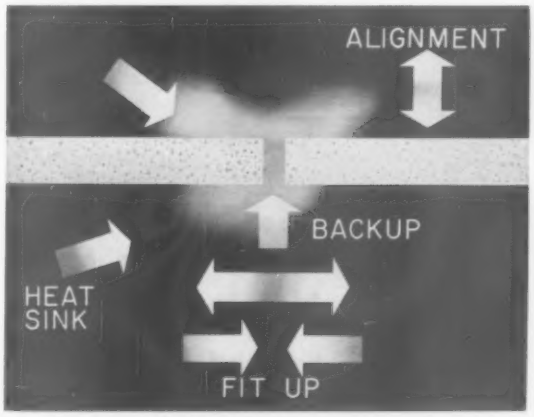


Fig. 7—Factors in electric arc welding

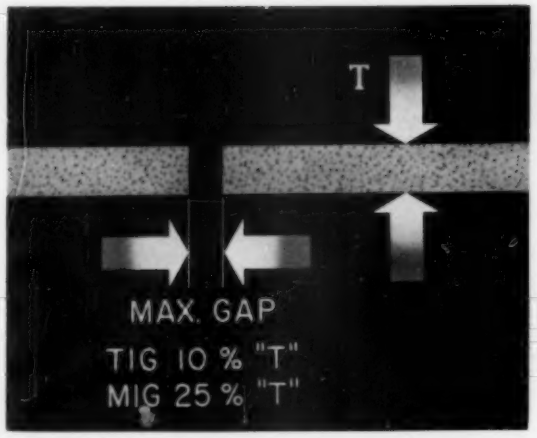


Fig. 8—Weld gap in manual and mechanized welding

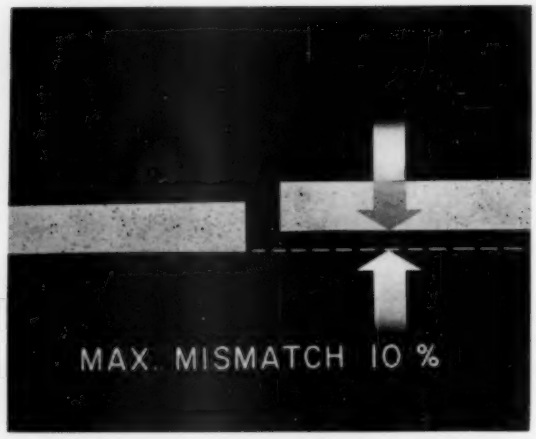


Fig. 9—Maximum mismatch for consistent weld results

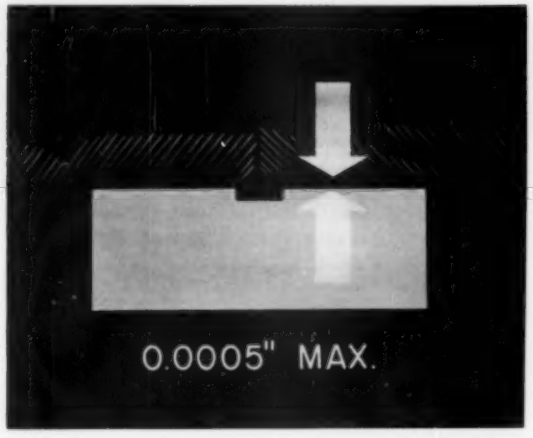


Fig. 10—Maximum fitup between backing and hold down bars

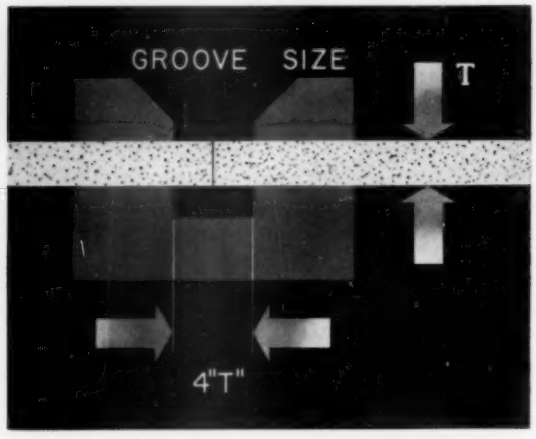


Fig. 11—Control of heat dissipation from weld area

with gaps up to 25% of the thickness of the thinnest sheet. The submerged-arc process, because of the fluid melt, and the arc force, also usually exhibits a gap tolerance of 10% of the thickness of the thinnest sheet.

As illustrated in Fig. 9, the maximum mismatch permissible for consistent weld results is about 10% of the thinnest sheet for all weld processes. This is true because the arc is attracted to the edge of the upper sheet; as a result, this edge overheats. At the same time, it is difficult to obtain uniform and consistent penetration at the bottom edge of the lower sheet. Mismatch does not always directly affect the surface condition of the finished weldment, but it has great influence on the consistency or repeatability of the welding process.

Backing bar or backing coppers as shown in Fig. 10 and the hold-down bars that contact the top side of the weldment act as heat absorbing devices. It is necessary to maintain a fit-up between these devices within 0.0005 in. if completely uniform heat transfer is desired. If the welding tooling, clamping pressures and part details cannot be held consistent with this tolerance, then it is necessary to design the backing and hold-down bar assemblies so that they exert only secondary influence upon heat absorption, permitting the edges of the sheets themselves to regulate the dissipation of heat from the weld area. When it is necessary to have the backing coppers play such a secondary role in heat control, then the design of the relief groove, and the spacing of the hold bars, must bear a relation to the thickness of the sheet being welded.

Figure 11 illustrates another interesting point. Ferrous materials (compared to aluminum or copper) have a low thermal conductivity that can be used to advantage to control the dissipation of heat from the weld area. In this case, the distance from the center line of the weld to the nearest heat absorbing copper is twice the thickness of the material being welded. This makes the work piece material act as a throttle to control the rate at which the heat travels into

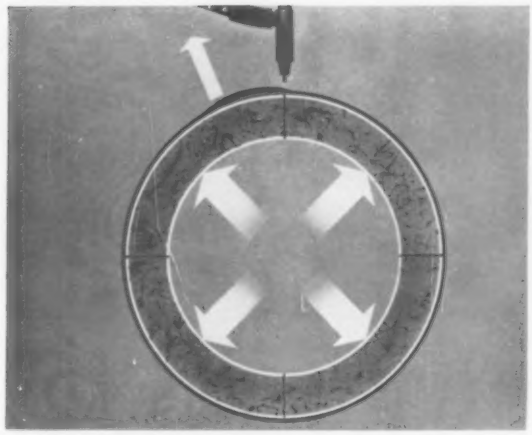


Fig. 12—Outside circumferential welding over an expanding mandrel

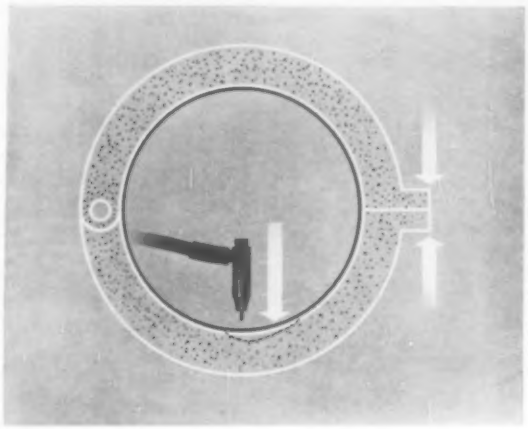


Fig. 13—"Inside-out" circumferential welding

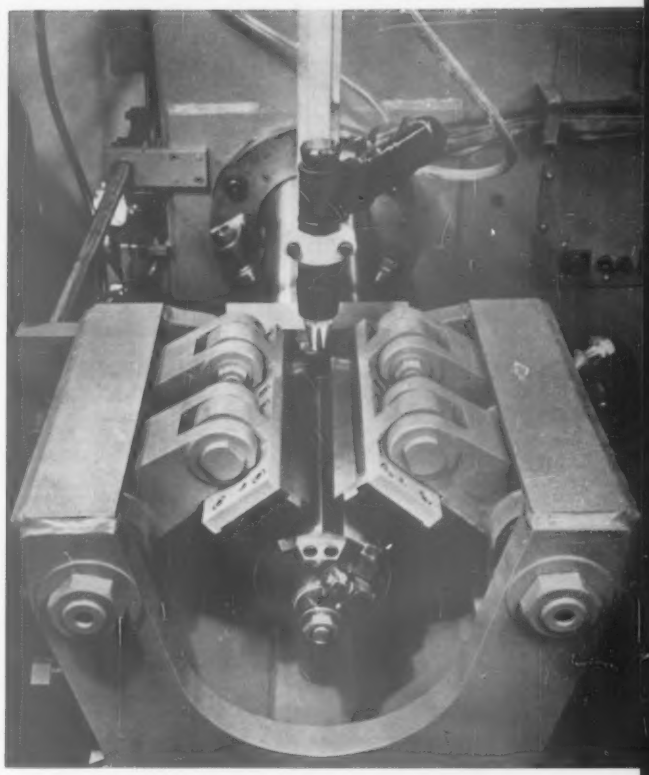


Fig. 14—Tooling for longitudinal welding machine for coffee maker

the copper; this creates a more uniform thermal condition around the weld. The relief groove can generally be made any depth that will ensure non-contact between the weld puddle and the backing bar. If an inert gas is supplied to the under side of the weld—as is sometimes done to prevent oxide formation—the surface tension of the weld puddle will be such that it will support a penetration bead approximately the thickness of the material in width, without dropping the bead against the copper.

The mechanical problem in welding longitudinal seams is relatively simple when compared to the mechanical problems in welding circumferential seams. For example, a longitudinal machine can be designed with sufficient clamping pressure to cause the sheet to be welded to lie uniformly against the copper backup bar.

In the case of a circumferential weld, however, the conventional method of welding from the outside over an expanding mandrel, as shown in Fig. 12, results in unpredictable thermal conditions surrounding the weld. This is caused by localized expansion of the metal under the arc.

If, as Fig. 13 shows, a backing clamp is placed around the outside of the weldment and welding proceeds from the inside, the heat of the weld (although it causes the same tendency for the metal to expand) merely serves to drive the metal into better contact with the backup, thereby improving control of the thermal conditions surrounding the weld. This "inside-out" welding approach, (where it can be used) has other advantages, as in the case of air-hardening and crack-sensitive steels. Since the weldment is not restrained by an internal mandrel, there is no tendency to induce stresses into the weld as it cools.

The foregoing only touches lightly upon the factors which enter into the design of precision welding tooling—tooling of the sort required to produce weldments where the "stick-em-together" technique of the past cannot meet modern day requirements. Welding speed, maximum permissible gap, mismatch, thermal control in the weld zone as a function of the welding tooling, and many other considerations must be measured against the results desired in the end product in order to determine what kind of welding tooling will best suit a given application.

Fig. 15—Corner circumferential welding machine for coffee maker

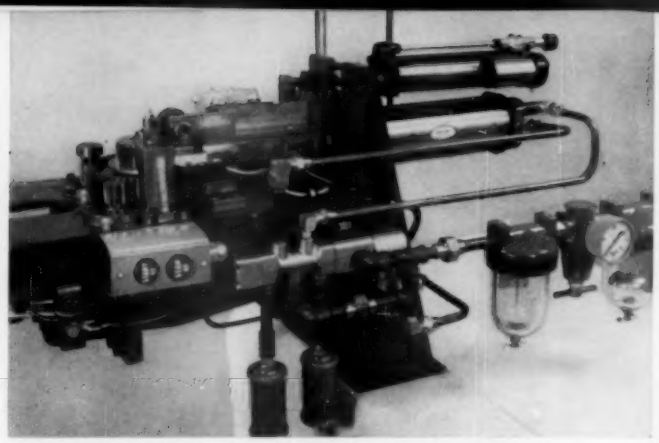


Fig. 17—Small-diameter aluminum-tube-welding machine

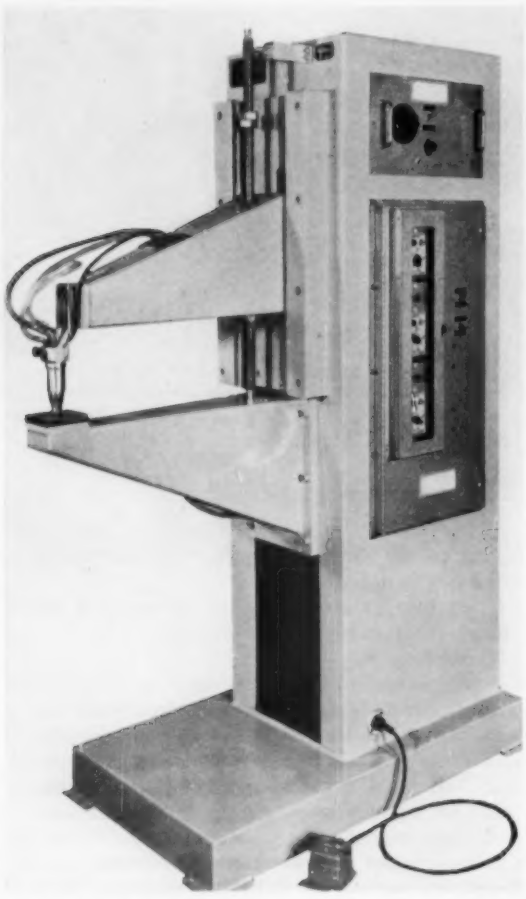


Fig. 16—A "single-point" gas tungsten-arc welding machine

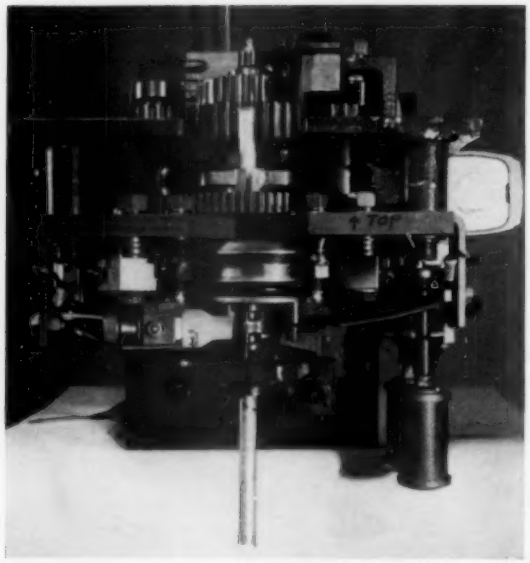


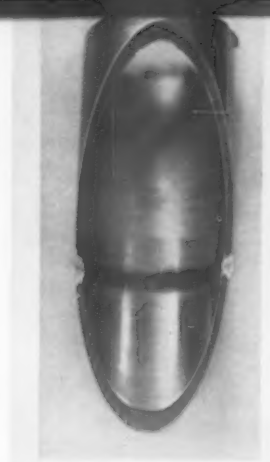
Fig. 18—Coaxial clamping of small diameter aluminum tubes

Applications

The machine and welding tooling shown in the lead photograph offer an outstanding example of what can be done when the philosophy of precision welding is correctly applied. This machine has been in use, two shifts per day for about 2 yr, welding the longitudinal seam in a widely known household coffee maker. A closeup of the tooling is also shown in Fig. 14. Here precision design of the welding tooling and cooperation with the customer resulted in sufficient control of both the stamping and welding processes to permit realizing a reject rate on these parts of less than 0.02%. This is particularly significant in view of the facts that the weld does not lie all in one plane—it is curved in a 128-in. radius—and nothing more than planishing and final buffing are required to make the part salable.

Backing bar deflection was avoided in this machine as well as the tracking problem which it would have posed. Instead, the clamping and backing reactions are absorbed internally within the tooling, which mounts as a replaceable assembly on the end of the motor-driven and electronically controlled travel ram.

Figure 15 shows a companion machine which makes a corner circumferential weld to secure the bottom in the coffee maker body. By supplying a small flow of argon to the underside of the weld in this application, it was possible to produce a completely smooth, internal corner fillet without casting



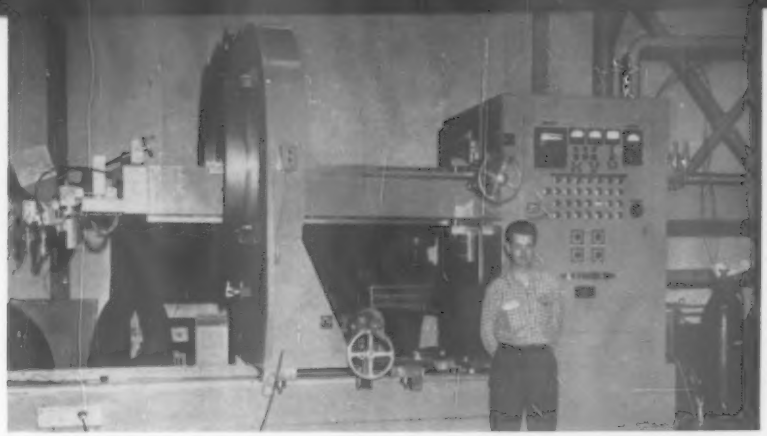


Fig. 20—"Inside-out" circumferential welding machine used on 54-in. diameter missile

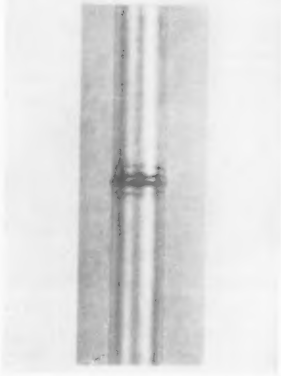


Fig. 19—Close-up of butt-welded joint of aluminum tubes

Fig. 21—Precision tooling for circumferential welding machine

against a backing. In this area, which could constitute an undesirable and even dangerous food trap, again no metal finishing is required to meet the manufacturer's exacting standards of surface finish.

There are times when the intended rate of production exerts a strong influence in the selection of tooling for a job. Figure 16 shows one simple version of a so-called "single point" gas tungsten-arc spot welding machine. Designed for lower production rates than its exotic cousin, the tape-controlled machine shown in Fig. 1, it is nevertheless equipped with the same welding process controls and is thus extremely useful in applications where consistency of results is an important consideration.

Figures 17 and 18 illustrate a machine which represents an unusual example of a solution to the problem revolving around the rate of heat input to the weld. In the refrigeration industry, for example, it is necessary to weld small diameter aluminum tubing to complete the refrigeration system. In the past, manual operators were trained to a very high level of skill in order to make the small welds that are required in these tubes. A machine was developed to produce these welds automatically wherein the torch rotates around the tube for approximately two revolutions. The original problem of mechanized welding was complicated by the fact that heat buildup advanced around the tube in excess of the speed of welding. In order to produce a satisfactory machine to weld these parts automatically, it was necessary to determine the rate at which the heat buildup preceded the arc around the tube and then to establish welding conditions that would weld in excess of this heat buildup rate. As shown in Fig. 18, each of two sets of coaxial clamping jaws holds one end of the two aluminum tubes to be joined; the ends are then welded at speeds ranging between 100 and 285 ipm, depending upon their size. Speeds above 285 ipm are not usable, because at this point power pulses from a 60-cycle source will produce skips in the weld. Figure 19 is a closeup of a welded joint between two aluminum tubes. The machine is capable of welding stainless steel, aluminum, copper, carbon steel and other weldable materials.

Obviously, if production rates can influence the nature of welding machines and tooling, so does the type of end product for which they are designed. Figures 20 and 21 show a pair of machines used for welding several stages of a 54 in. diam missile.

Fig. 22—"Inside-out" longitudinal welding machine used for 5-ft long welds

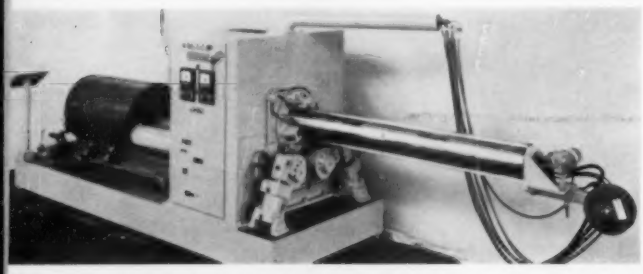


Fig. 24—Longitudinal welding machine for missiles with weldment clamped in place

Figure 20 is an "inside out" circumferential welding machine; it is designed to use both gas tungsten-arc and submerged-arc welding on a AMS 6434 material. Essentially it is a lathe type machine, using an idling headstock and tailstock, with a motor driven clamping member (or catshead) interposed between the two. This catshead contains the 600° F preheating elements, as well as the stress relieving elements, and clamps the parts at the weld joint. The welding heads are carried by the ram which, in turn, is supported by the column on the right. This column also houses all the machine controls.

In spite of its size, great precision was required and built into this tooling as illustrated in Fig 21. For example, the actual centers of rotation of the headstock, tailstock and catshead clamping members are coincident within 0.008 in. regardless of their position on the 40 ft long track, and in spite of the 600° F preheat temperature. This high temperature also made special torches and other welding equipment a "must" for this job.

Despite its cost, such precision is necessary on equipment of this size. The parts to be welded in this machine could not be pretacked. Because of the restrictions governing the size, shape and continuity of the penetration bead, plus an extremely tight tolerance on lack of straightness or "banana" in the completed weldments, component parts fit-up had to be perfect to start with and had to be held that way while welding progressed.

In Fig. 22 is seen a companion machine to the previous one. It makes "inside-out" longitudinal welds up to 5 ft long in 54 in. diam shells and skirts.

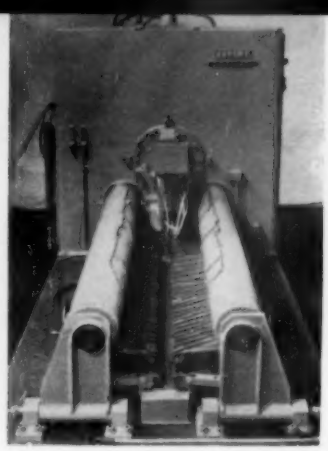


Fig. 23—"Torque-tube" clamping system for longitudinal welding of missiles

Like the other, it provides 600° F preheat and is equipped to weld with both the submerged-arc and tungsten-arc processes. Pilot-arc starting is used to start the tungsten arc on both machines. Here again, extremely high quality welds were required, and very close control of the penetration bead was necessary.

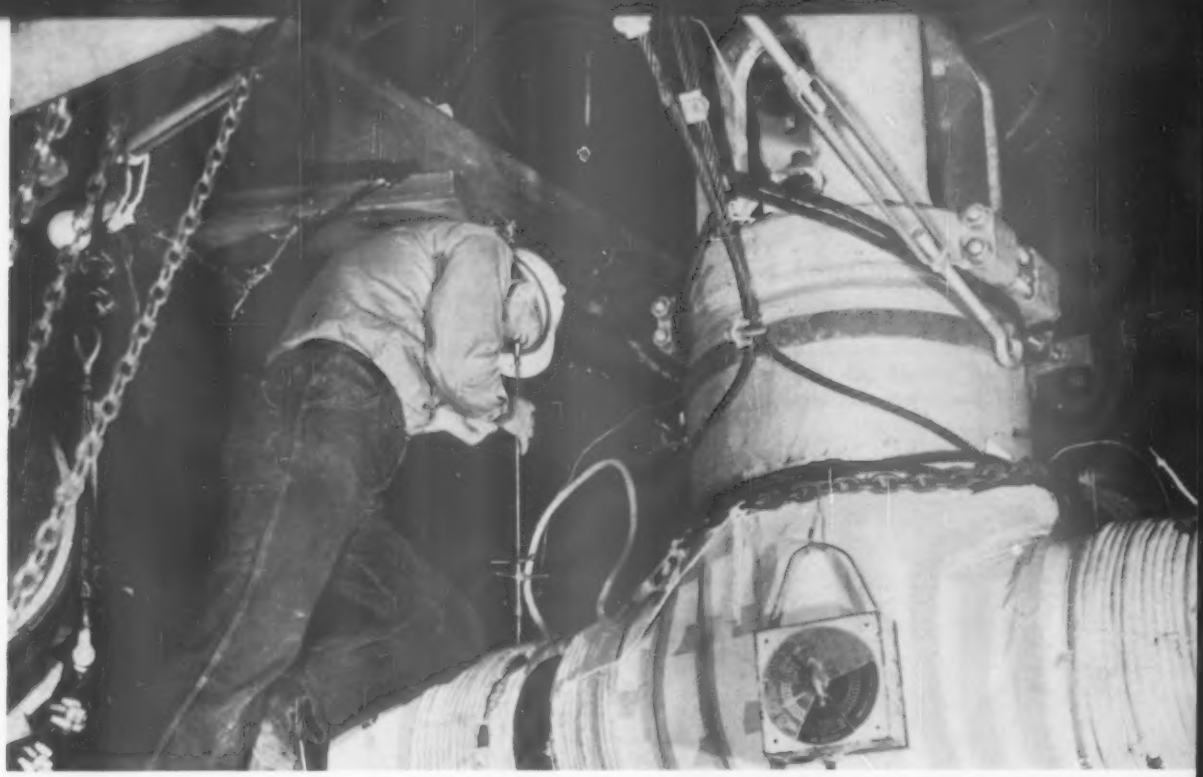
In order to avoid introducing fixture deflection problems into the picture, a unique "torque tube" clamping system was chosen to deliver clamping force to the workpiece through a series of heavy, closely calibrated, cantilever springs. This system, as illustrated in Fig. 23, coupled with the "inside-out" welding approach, made it possible to put the weld backup members on the machine base, from where the reaction forces are transmitted directly to the floor or foundation. This automatically removes what would otherwise be a significant variable in a conventional fixture and makes it possible to hold the weld in a perfectly flat plane parallel to the path of travel of the ram which carries the welding equipment. The ram itself is built to track true within 0.005 in.

Figure 24 shows a similar machine with a weldment clamped in place. In this case, the vessels to be welded ranged up to 6 ft in length and were 31 in. in diameter. Here the gas metal-arc process was employed to make the weld.

Conclusion

Welding has progressed from the manual age, through noncritical mechanized, to precision welding. The essential nature of welding tooling must change. Precision weldments are made today to tolerances approximating those of machined parts. In order to do this, precision-welding tooling is a necessity. For this type of work, the old time "angle iron" and "C" clamp type of tooling is completely inadequate.

The successful precision welding machine builder must know and apply to his equipment those fundamental process and tooling requirements described. A welding machine can be made to remember and repeat its actions with the utmost precision. However, it cannot be called a precision welding tool, unless careful provision has been made in its construction to team up such factors as: selection of the proper travel speed together with adequate control of mismatch, maximum gap in the seam, adequate clamping, proper heat sink in the welding tooling and a host of others.



Operator looking into the viewing lens to obtain a clear image of the weld from the pipe interior. To use instrument, he rotates the remote lens 360 deg to scan the entire weld. The position of a defect is quickly located by noting the angular displacement on the rotation control

Optical **Scanning of Welds**

From Pipe Interior Provides Increased Inspection Reliability

in the fabrication of joints in high pressure steam lines

BY MICHAEL J. GRYCKO

The problem of inspecting welded joints in high pressure steam lines, where structural integrity is vital for safe operation, has been solved by use of an optical device to scan the weld from the pipe interior. The optical method furnishes the two requirements essential for this type of inspection: (a) reliability in that accurate determination of weld quality is a *must* because of the rigorous service to which the line is subjected, with pressures and temperatures up to 2500 psi and 1070° F; (b) speed since, during welding, the condition of the root pass must be determined quickly before the filler metal is added.

These results have been impossible to achieve until now with other methods. The technique is used in the erection of main steam, reheating, and boiler feed lines.

MICHAEL J. GRYCKO is Welding and Equipment Supervisor, William A. Pope Co., Chicago, Ill.

Insert Ring Improves Weld

The optical instrument under discussion here is called the Inspect-O-Scope.* It is used to inspect the butt weld interior immediately after the root pass has been made. Here the principal object of inspection is to check the completeness of fusion between the lands and a suitable insert ring. When using this insert ring, a small amount of silicon in the ring has been found to improve weld quality by acting as a degassifier and fluxing agent. The insert ring must be completely fused by the first or root pass, because any unfused area would set up stresses that could endanger the weld when high pressures and temperatures are encountered. The insert ring improves weld metal quality, practically eliminates porosity and replaces backing rings, which tend to produce cracks in the weld metal after extended

* Product of Size Control Co., Chicago, Ill.

service in critical systems. The cracking usually takes place because a backing ring, when used in a line at high temperature, picks up heat at a faster rate (at start up) than the base weld metal and causes unequal expansion problems in the root area.

The pipe used in this application is usually A-106 or A-335 material, and welding is performed by the gas tungsten-arc process on the first pass only. The edges joined are shaped to form an extended "U" bevel with the insert ring fitted between land extensions. The surfaces are wire brushed and solvent-cleaned before welding. Internal surfaces are matched within $^{1}/_{16}$ in. The ends are then matched by grinding or filing to secure maximum contact. The insert rings are made from a material compatible with the base metal. The pipe interior is then purged with argon before welding is begun.

Pipe inspected by the optical technique ranges in diameter from 8 to 24 in. and in cross section thickness from $^{3}/_{4}$ to 4 in. An area, which is shown op-

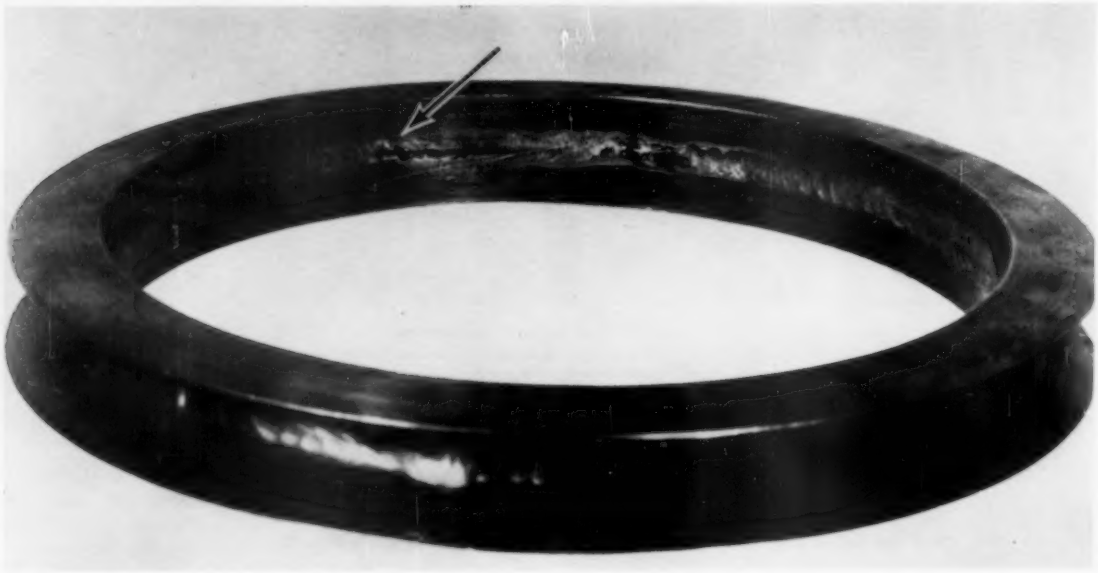


Fig. 1—Unfused portion of insert ring (arrow) as seen from the pipe interior shows up clearly when viewed by the proper optical device. Inspection speed is vital because additional filler passes must be made over the root pass before the weld joint can be cooled for any reason

Fig. 2—Optical device to scan pipe interior is hinged 8 in. from the bottom to allow the leg (containing the lens and light source) to be raised to a position parallel to the tube line, with the lens and light directly under the weld

tically to contain an unfused portion of the insert ring, is given an additional root pass immediately—Fig. 1. The instrument shows precisely where the defect is by "clocking," or angular determination.

Bright Light Source Increases Image Clarity

The optical instrument used in this application is illuminated with a 100-w airplane lamp, with a rheostat ranging from 8 to 24 v. The inspection device can work in temperatures over 400° F and, under some circumstances, joints at 780° F have been inspected. A special arrangement of lenses makes the image of the interior weld so clear that any defect will show up immediately. The inspection procedure must be performed while the joint is hot, because it is necessary to have at least one-third of the weld groove filled before it can be allowed to cool.

The optical instrument was made to fit the specific needs of this application. The unit is threaded into the radiograph access hole, approximately 6 in. from the welded joint, immediately after the root pass has been made. The instrument, essentially a rigid tubular structure approximately 32 in. long, is thus fixed in position, with its lower portion extending into the pipe interior. The lower end is hinged to form a leg approximately 8 in. in length. Through controls on the exposed portion of the instrument, the leg can be raised to a position parallel to the line of the pipe, so that the lens and light source at the end of the leg are directly under the weld—Figs. 2 and 3. Another control allows the leg to be placed at the center of the pipe.

Lens Rotation Allows View of Entire Weld

The operator looks into the viewing lens and, by rotating the remote lens a full 360 deg through another control, he can obtain a well-lighted, clear view of the entire weld—lead photograph. The precise location of a defect is quickly determined by noting the angular displacement on the rotation control.

The instrument works on the principle that a piece of glass with a radius has the ability to bend light rays and brings an image into focus at a certain distance from the lens. By the proper combination of various optical elements, an image can be transmitted to a point where an operator can view it easily. The optical system of the instrument is relatively simple: It consists of a deflector, objective lens, field lens, transmission lens and an eye lens.

Magnification is determined by the eye lens, while the degree of viewing area is determined by the objective lens. Therefore, systems can be designed for different magnification and viewing areas. The unit is designed so that it is focused at infinity to allow the operator to obtain a sharply focused image of the inspected surface from any distance. Use of the instrument is thus simplified because individual focusing adjustments are not required.

Conclusion

Previously, the pipe welding inspection job was attempted with a surgical gastroscope, but its specialized design for stomachs, not power piping, made the operation difficult. Gamma-ray inspection or ultrasonic testing are the usual methods of locating defects not apparent on the surface, but these have several disadvantages for inner surface inspection, the most important being: (*a*) inability to operate successfully on materials at preheat temperatures (400 to 800° F), and (*b*) too slow an inspection speed, so important to successful contractors.

With the optical inspection device, all of the guesswork, apprehension and possible expensive repairs are eliminated by the simple expedient of actual visual inspection, on both surfaces, of the most critical area of all, the first pass.

Burn-through areas in joints with standard backing rings can also be positively identified, thus eliminating some of the guess work in gamma-ray film interpretation.

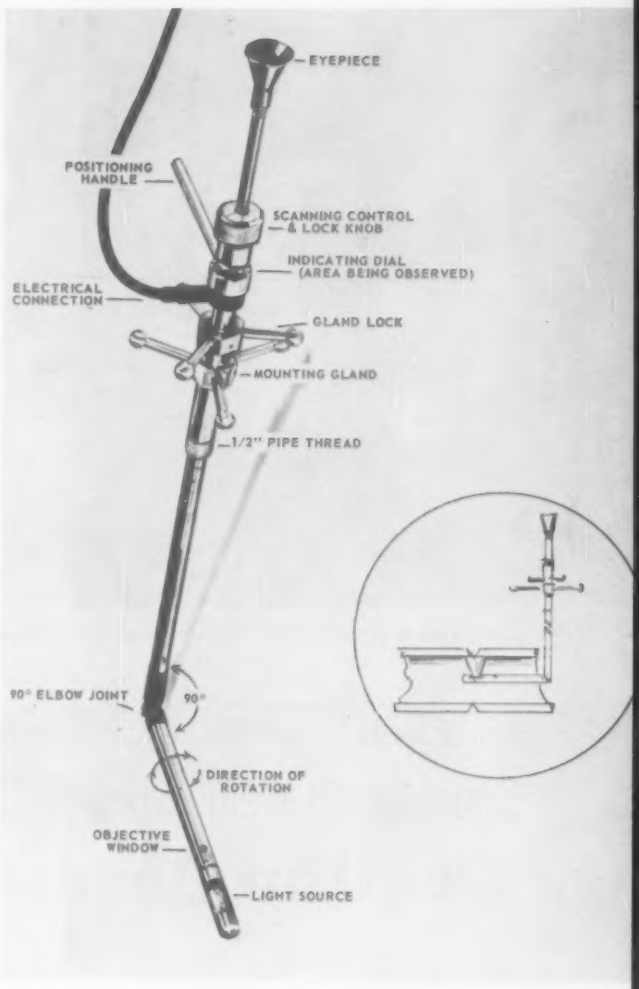
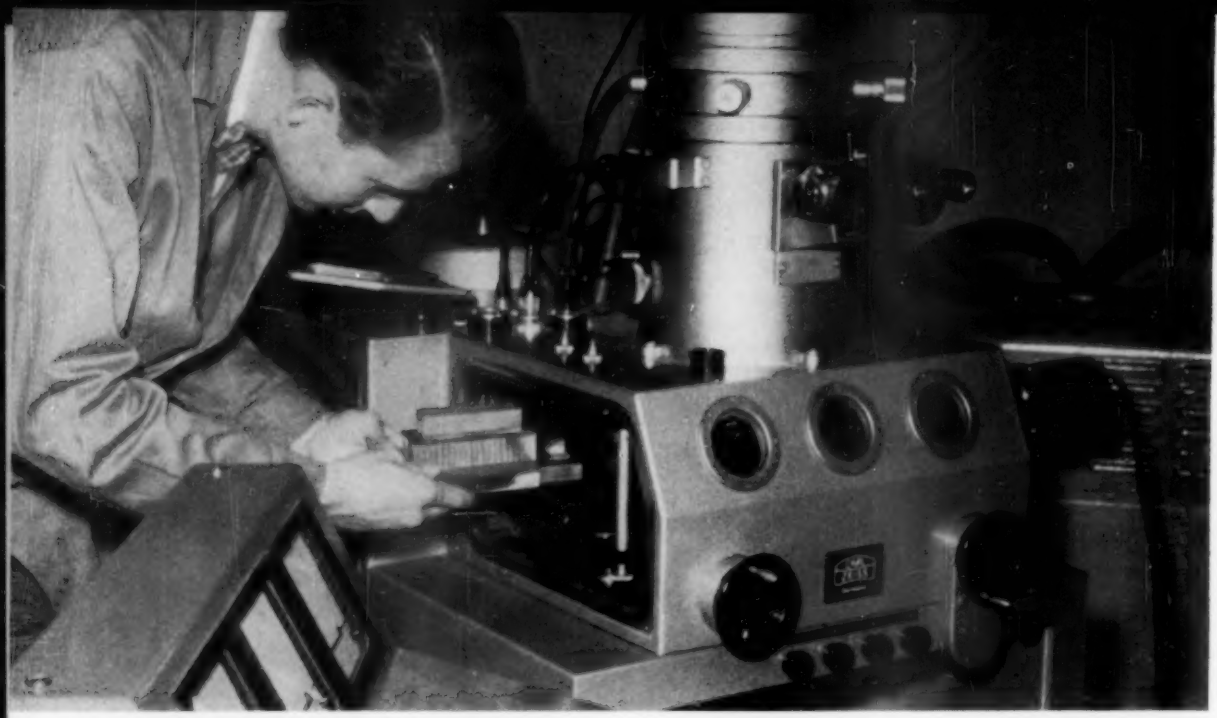


Fig. 3—Schematic of optical device to scan welds in pipe



Loading welding chamber with honeycomb sandwich to be welded with electron beam process

Narrow welds in 10-in. thick material are foreseen for the future in

Super-Depth Welds Made With a High Energy Density **Electron Beam**—A Revolution in Welding

BY E. R. AEMISEGGER, JR. AND HANS A. NYENHUIS

A new welding process, which has evolved in the last several years, now meets the pressing needs of the metal fabrication industry. The idea of localized heating by the bombardment of a work piece with an electron beam originated many years ago, but the development of sophisticated equipment necessarily had to await the demands and challenges of atomic and space age designs.

Electron beam welding machines derive their unique effects in the following manner: Basically, a beam of electrons is emitted from a cathode, accelerated to a high velocity, and sharply focused to produce an extremely high energy density.

Nature of Electron Beam Welding

The unique nature of electrons has made it possible to control their activities with much precision. Thus, with the advent of sophisticated electron optics, enormous amounts of energy may be concentrated over very small areas. Actually energy densities on the order of 10 billion watts per square inch are now easily attainable with commercial equipment—Fig. 1. The significance of this energy density capability, however, is not yet fully appreciated in that new and interesting phenomona are being discovered daily.

It may easily be understood that the bombardment of a solid by electrons necessarily results in the conversion of kinetic energy to thermal energy in the solid. In the case of high energy densities, however, this is not the complete story. It has been normally accepted that electrons are quickly diffused in a very small layer of material, and subsequent heating results from radial thermal conduction from the area of impingement. This, however, does not account for the unusually high depth to width ratios resulting from the use of high energy densities—Fig. 2. Indeed, depth-to-width ratios of heat-affected zones exceeding 25 to 1 have been experienced in various materials. Apparently the electrons are capable of vaporizing a fine path through the entire thickness of a solid resulting in localized "internal heating." It may be readily shown that electrons actually emerge

E. R. AEMISEGGER, JR., is an Engineer and HANS A. NYENHUIS is Manager of the Research Laboratory and Service Dept., Hamilton-Electrona, Inc., New York, N. Y.

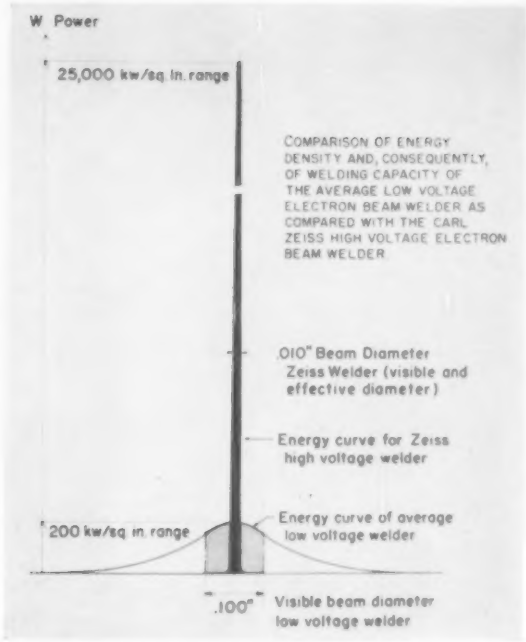

W Power
25,000 kw/sq. in. range
COMPARISON OF ENERGY DENSITY AND, CONSEQUENTLY, OF WELDING CAPACITY OF THE AVERAGE LOW VOLTAGE ELECTRON BEAM WELDER AS COMPARED WITH THE CARL ZEISS HIGH VOLTAGE ELECTRON BEAM WELDER
.010" Beam Diameter Zeiss Welder (visible and effective diameter)
Energy curve for Zeiss high voltage welder
200 kw/sq. in. range
Energy curve of average low voltage welder
.100"
Visible beam diameter low voltage welder

Fig. 1—Energy densities of low- and high-voltage electron beam welding machines

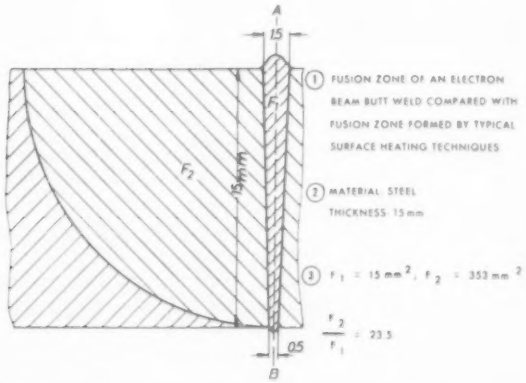

A
15
F1
F2
15 mm
1 FUSION ZONE OF AN ELECTRON BEAM BUTT WELD COMPARED WITH FUSION ZONE FORMED BY TYPICAL SURFACE HEATING TECHNIQUES
2 MATERIAL: STEEL THICKNESS: 15 mm
3 F1 = 15 mm², F2 = 353 mm²
F2/F1 = 23.5
05
B

Fig. 2—Fusion zone formed by electron beam welding

from the opposite side of the material upon which it impinges. After operating parameters were properly adjusted, as many as four separate layers have been penetrated by the electron beam—Fig. 3. Interestingly, a refocusing of the electron stream takes place within the material itself and makes possible some very interesting applications which are described later. The most important effect arising from the use of high energy densities in this propensity for internal refocusing accompanying the penetration of solid materials.

The consequence of internal refocusing may now be more fully appreciated. In addition to an internal heating affect resulting in extremely high depth-to-width ratios of the heat-affected zone, the refocused beam may actually penetrate material thicknesses exceeding an accumulation of 1 in. This now brings to reality a revolutionary method of localized heating. The fabrication of materials or components with unique resultant properties is therefore practical—Fig. 4.

It is possible to draw an analogy to this process by the passing of a white-hot wire through a solid block

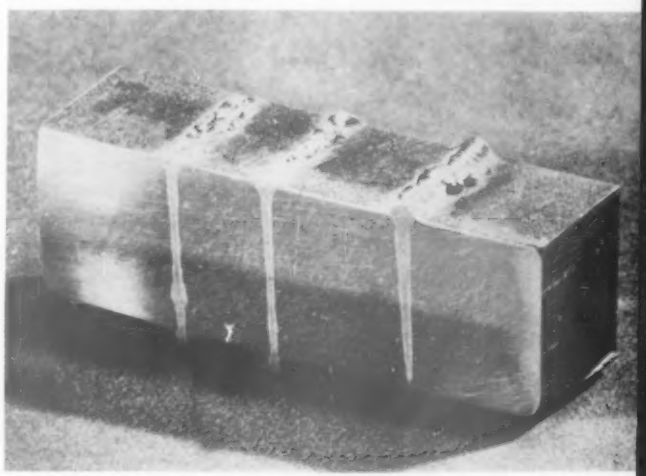
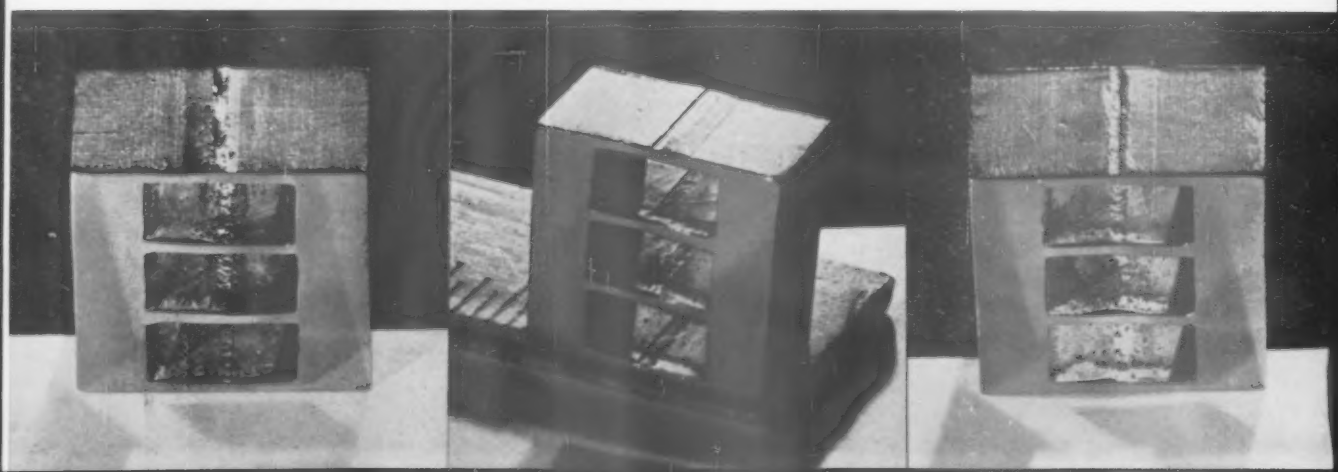


Fig. 4—Electron beam penetration in 1-in. thick Type 302 stainless steel

Fig. 3—Blind welding capability of high voltage electron beam welding machine—four welds in stainless steel completed in single pass



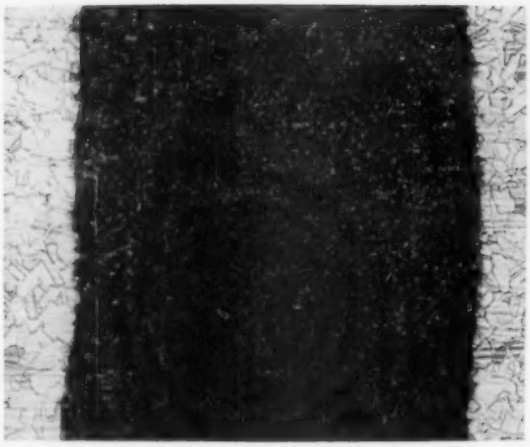


Fig. 5—Heat-affected zone adjacent to electron beam weld

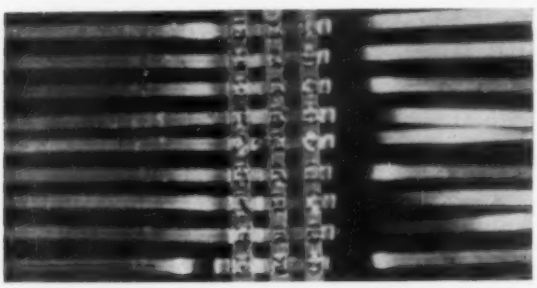


Fig. 6—0.002 x 0.010 in. thick copper wires welded to metallized alumina substrates with electron beam process

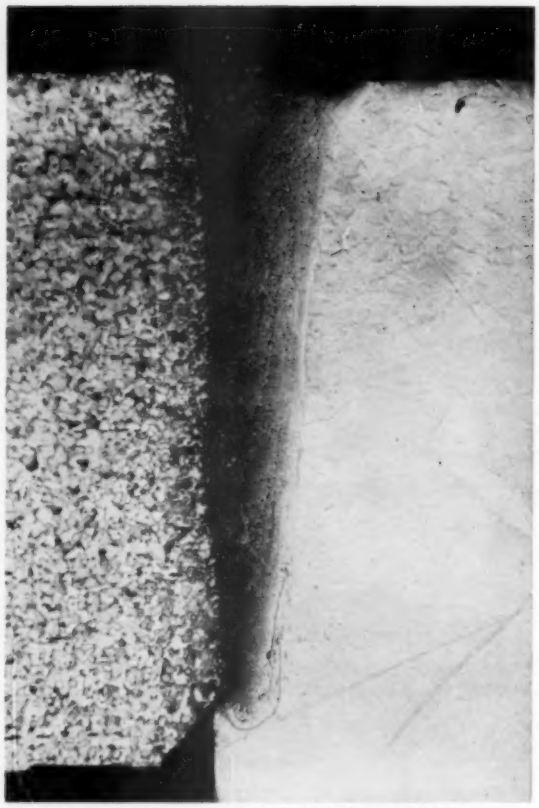


Fig. 7—Electron beam welding of dissimilar materials

of ice. Consider now the passing of an electron beam through a solid material. Parameters influencing energy density having been properly adjusted for a specific condition, it is possible to move the work piece at a given velocity under the electron beam. The results are surprising, for it is found that in addition to a remarkable weld geometry, extremely rapid table speeds may be used to accomplish them. It is also found that, as a result of very rapid heating and cooling rates, fine grain sizes are produced with extremely small heat-affected zones—Fig. 5.

In general, it may be shown that high energy density electron beams produce narrow, sound, fine grained welds at very high speeds. A further implication may now be appreciated. The high welding speeds and energy densities provide conditions which drastically reduce the distortion and shrinkage usually associated with normal techniques of materials joining.

As may be seen, Fig. 5 illustrates a limited heat-affected zone adjacent to the weld. The rapid heating and cooling rates have restricted resultant recrys-

Fig. 8—Standard electron beam welding machine

tallization and grain growth of the austenite to a smaller grain size than the parent metal. The shearing of the test coupon edges resulted in cold worked edges which subsequently produced recrystallization in the annealed materials.

Applications and Installations

Since the advent of commercially available electron beam equipment, many interesting applications have evolved. The flexibility of parameter variations has made possible micromachining, micro- and macroprecision welding, spot alloying, spot annealing and vapor deposition of thin films. For example, Figs. 4 and 6 demonstrate the capabilities of electron beam to effectively weld materials varying in thickness from 0.002 to 1 in. In addition, welding of materials which differ greatly in geometry or melting points is easily accomplished with high energy density beam. This is made possible because the time interval required to raise each to its respective melting point is practically identical—Fig. 7. In another example, an interesting "T" weld results when the beam is purposely deflected to provide material to generate a radius on the bottom interfaces. Filler metal additions may be made to reduce or eliminate the undercut evident in this photograph.

Construction of Electron Beam Welding Machine

Figure 8 shows a standard electron beam welding machine whose work chamber will accommodate parts or test specimens. The machine consists of the following main parts:

1. High voltage transformer with control desk; primary 220 v, secondary up to −150 kv and up to 20 ma.
2. Gun supply unit containing pulser, bias voltage and filament heating circuits.
3. Welding unit consisting of machine frame with built in vacuum pumps, welding chamber with X and Y table, and the electron optical column.
4. Control console containing the remaining controls.

The upper part of the electron optical column contains the electron beam source of the so-called telefocus system. The electron beam source is at the same time an electrostatic lens whose focal point is approximately in the center of the movable tungsten diaphragm. The electron beam source consists of a tungsten cathode, a control grid or bias cup, and the anode. Shape and position of the control grid and the anode are most important in effecting such high energy densities. The accelerating voltage is adjustable from 0 to −150,000 v.

Immediately below the anode are the electromagnetic adjusting systems which are placed in two levels, each adjusting system containing two pairs of coils placed 90 deg to each other. The coil currents and the magnetic fields generated by the current flow through the coils, and their directions are adjusted by turning the four knobs on the front of the machine frame. With help of these magnetic fields, it is possible to align the beam to the electron optical axis of the magnetic lens.

The mechanically movable water-cooled tungsten diaphragm collects stray electrons due to misalignment of the filament and the bias cup in relation to the axis of the anode and magnetic lens; it also protects the light optics of the stereo microscope mounted immediately below this point.

The built-in stereo microscope allows the operator to watch the welding process and make it possible to align and focus the electron beam very precisely on the work-piece since the electron beam passes through the center of the objective lens.

The magnification of the microscope is varied between 6 and 40 × from the outside. The binoculars are visible on the lower section of the electron optical column. Below the objective lens is a protection glass and a mechanical shutter which protect the objective lens from becoming coated with evaporated material.

Below the optical viewing system is the magnetic lens which focuses the electron beam to a very small spot. The focal point can be easily changed by varying the current in the coil or by changing pole pieces for extended work distances.

Below the magnetic lens is a deflection system, which consists of two pairs of coils placed 90 deg apart to deflect the beam in the X or Y direction. This is done by connecting the different pairs of coils to a 60 cycle voltage source. The width of the deflection adjustable from 0–0.350 in., is controlled by changing the amplitude of the output of the a-c voltage source. This makes it possible to produce a wide welding zone without losing energy density for such applications as the welding of poor fit-ups from sheared edges or for surface polishing or preheating.

Below the electron optical column is the vacuum or welding chamber which contains a work table movable in the X or Y direction simultaneously. The table is driven with two handles visible on the front of the chamber. The Y motion is manually operated. The X motion is manually or automatically operated and is steplessly controllable between 3 and 28 ipm. The motor will switch off or change its polarity when the work table reaches the limit switches mounted on each end of the chamber. The table motion can be stopped and started at any position by pushing the right foot switch visible in the knee space of the machine frame.

The work chamber has two doors—one on each side to change the work piece. It is possible to mount extensions on each end of the vacuum chamber for longer work pieces. There is also an 8-in. diameter door on the bottom of the chamber to accommodate special work geometries on tooling.

The machine frame has a built-in vacuum system which evacuates the welding chamber and the electron optical column to a pressure of 10^{-4} mm Hg in. approximately 10 min. It takes about 11 min to break the vacuum, change the cathode when defective, and evacuate the chamber to 10^{-4} again.

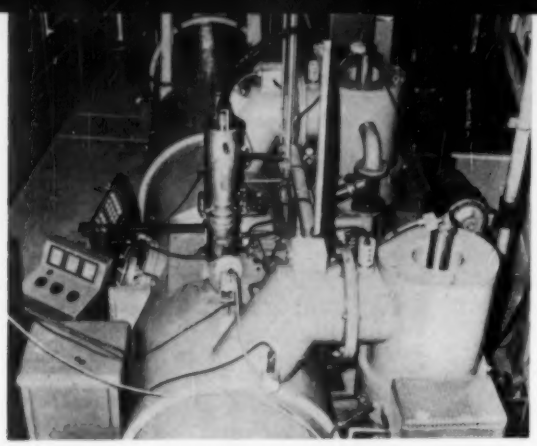


Fig. 9—Use of electron beam welding machine with a chamber

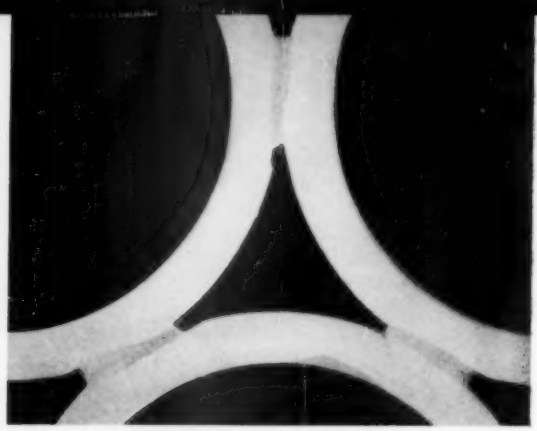


Fig. 11—Three 0.010 in. thick wall tubes welded tangentially

Fig. 10—Beam T welds in stainless steel—inner T joint welded tangentially from one side and outer T joint welded through tube wall. (Parts 0.040 and 0.080 in. thick)

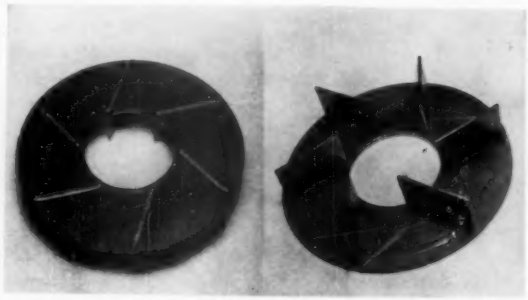


Fig. 12—Rotary vane assembly as produced by burn through T welding technique

The complete electron optical column and the welding chamber are lined with lead for X-ray shielding purposes.

To the left of the machine is the high voltage transformer and the high voltage control desk. The accelerating voltage is adjustable from 0 to −150,000 v while the beam current may be varied from 0 to 20 ma.

In the gun supply unit, the voltage for the bias cup and the filament heating is added to the high voltage. The bias voltage can be pulsed so that the beam may arrive at the work piece in the form of pulses with controls for frequency and pulse duration.

The control console visible to the right of the machine contains the following:

1. Electron magnetic lens current control.
2. Beam current control (bias voltage) and filament heating control. The beam can be switched off with the left foot switch mounted in the knee space of the machine; a vacuum measuring meter and on-and-off switch for the pulser are included.
3. Voltage source and control switches for the upper and lower adjusting system and the deflection system.
4. Vacuum pumps and magnetic valve control, on-and-off switch for the NTC (negative temperature coefficient) vacuum gage.
5. Main switch, phase control, and switches for stage motor and lights.

There are several electron beam welding machines

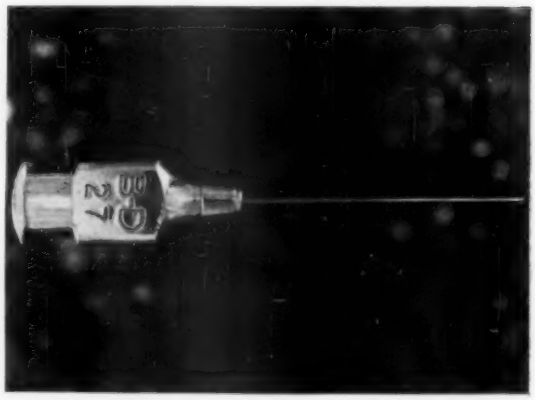


Fig. 13—Sealed hypodermic needle as welded without plug or filler metal with electron beam process

installed with large vacuum chambers (10 to 26 ft long) to weld large parts in production—Fig. 9. The only difference between these machines and standard machines are the chamber sizes. The welding unit, itself, can be adapted to any size vacuum chamber or to existing dry boxes.

By connecting the electron optical column to a big chamber, the relative motion between electron beam and work piece will be achieved by moving the work piece or the electron optical column. By simultane-

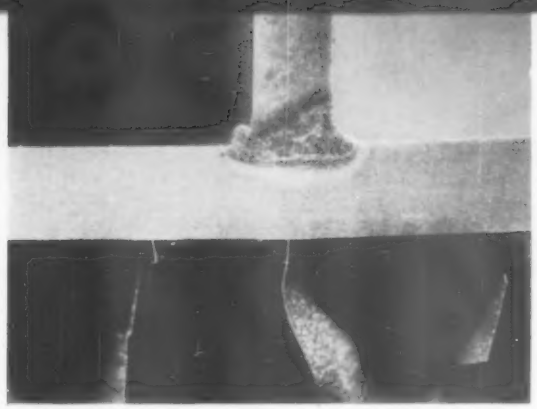


Fig. 14—Reinforcement to skin sheet showing 100% fillet weld penetration—welding carried out at a 7 deg angle

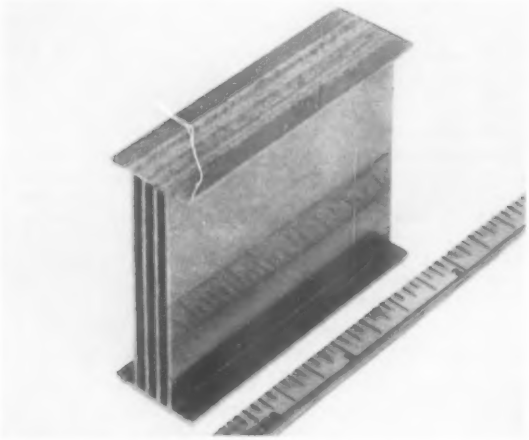


Fig. 15—Burn through T welds in nuclear fuel element

ously moving both parts and with the necessary electronic programming, it would be possible to weld any kind of configuration or pattern. Because of the distance between the operator and the electron optical column on big chambers, the welding process may be observed by closed circuit television.

This electron beam welding machine is a high performance flexible unit with which it is possible to make all the different welds shown in Figs. 10 to 16.

Properties of Electron Beam Welds

The high energy density welding of metals and alloys has produced some remarkable results. It may be said in general that, if metallurgically compatible materials are joined by this process, the resultant joint is sound. Indeed, such materials as H-11 tool steels, refractory alloys, metals to ceramic bonds, tool steels, and a wide variety of nonferrous materials have been joined to produce unusually high joint efficiencies.

Consider now the data graphically shown in Fig. 17. The plotted points represent a statistical distribution of fracture strengths of butt welded Type 302 stainless steel weld coupons.

The ordinate is so proportioned that a normal gaussian distribution about a mean would generate

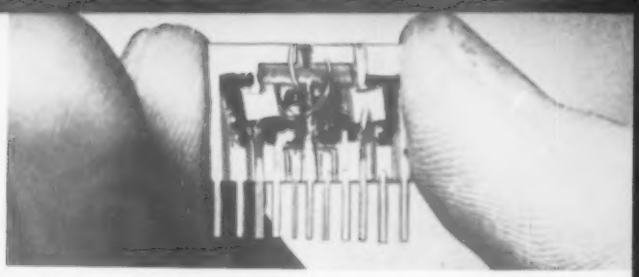


Fig. 16—Micro wafer fabricated with electron beam welding

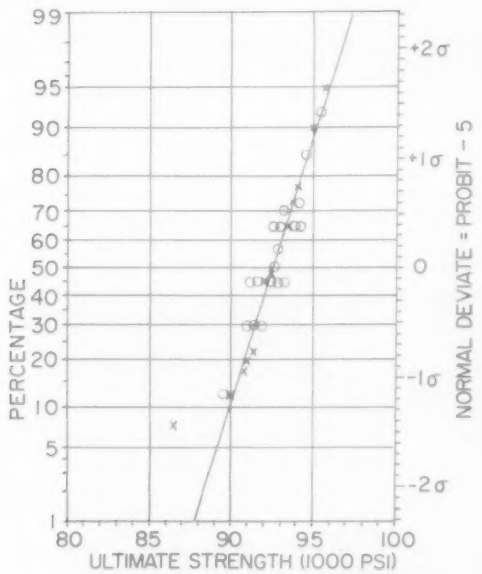


Fig. 17—Statistical presentation of electron beam weldment fracture strength results from butt welding annealed 0.062 in. Type 302 stainless steel. Symbols as follows: X—as-welded with fracture in weld; O—as-welded with fracture in base metal. Mean = 92,500 psi, and standard deviation (σ) = 2000 psi. Percentage, (p) calculated as follows:

$$p = \frac{100}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{x^2}{t}} dx$$

a straight line plot. The plot of tested values indeed forms a remarkably straight line plot about a mean whose value equals the base metal strength with a standard deviation of 2000 psi.

Bend test results indicate the welds withstood a 120 deg bend about 1T radius in a normal root bend test.

Future of Electron Beam Processing

The potential of electron beam processing has hardly been tapped. Recent proprietary work has indicated that the welding of 10 in. thick materials may be an imminent reality with high energy density devices.

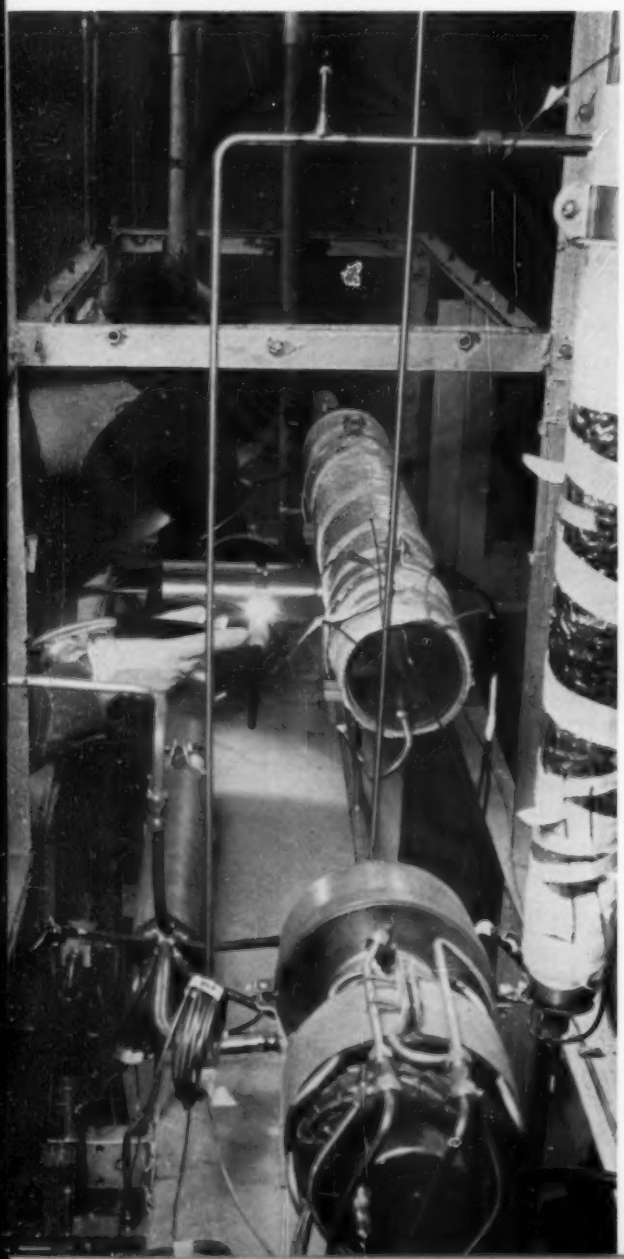
With increasing emphasis on reliability, quality and reproducibility, electron beam welding techniques show promise of extended usage in even the most common commercial applications as well as in new highly specialized material joints including tungsten to graphite or refractory alloys to brittle ceramics.

High quality welds are obtained using either butted-joint design or circular cross-section preplaced inserts in

Root-Pass Procedures for Inert-Arc Field Welding of **Titanium**

BY W. J. LEONARD

Welding titanium systems with commercial gas tungsten-arc welding equipment



ABSTRACT. Various root-pass welding techniques which would lend themselves to welding titanium in air were tried in an attempt to obtain high-quality welds with flush root contour. Such welds were achieved with no filler metal addition and a butted-joint design. For an insert-type weld, a circular cross-section preplaced insert was shown to be the most satisfactory. Such geometry resulted in welds of high quality and with a flush contour; however, the weld joint preparation and fit-up were difficult. Difficulties were encountered with inserts of other geometries, including the commercial type widely used for stainless steel.

Introduction

Air welding techniques for the manual gas tungsten-arc welding of commercial titanium for nuclear and chemical application have been previously described.[1] In applications where high-quality tube and pipe welding are required, there is often an additional requirement to have a very uniform root contour with the weld metal approximately flush with the inner pipe or tube surface.

In field welding titanium, root passes, using manual filler-wire-addition techniques, failed to accomplish this as some root reinforcement inevitably resulted. Previous stainless steel welding experience had shown similar objectives could be accomplished in that material by the use of preplaced root insert techniques. Thus, similar techniques, or possibly a fusion root pass with no filler-wire additions, appeared to be the most promising method for obtaining the desired quality in titanium root passes.

Since this welding investigation was performed with the intent of developing techniques primarily applicable to all-position field welding rather than a fixed-geometry production job, it was desirable that the developed process be an air-welding process Air welding as used in this report is defined as welding in ambient air with commercial gas tungsten-arc welding equipment, using no auxiliary shielding devices. Field welding virtually eliminates the use of specially constructed leading or trailing torch attachments designed to the geometry of a specific

W. J. LEONARD is with the Metallurgy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

work piece or the use of inert-gas chambers or dry boxes. As in all air welding of titanium, a limitation is imposed on welding variables, such as heat input, which may lead to contamination by air when the limited shielding capabilities of the particular techniques are exceeded.

In many materials, such as alloy steels, stainless steels or high-nickel alloys, the metal added during welding is of a modified chemical composition. Thus the use of a filler wire is mandatory, whether hand-fed or as a preplaced insert. In titanium welding, however, the situation is somewhat different in that there are no metallurgical changes or elemental losses which may result in an unsound weld being produced. There is, however, the possibility of an unintentional nitrogen and oxygen pickup which may tend to increase the spread of the mechanical properties between the base-metal and weld-metal portion of the weldment. However, if the contamination is minimized by close control during welding, the difference in properties between filler and base metal does not appear significant. Therefore, it is felt that satisfactory welds without filler-wire additions are practical.

Materials and Equipment

Commercial titanium was used both as base metal and as preplaced inserts. Standard gas tungsten-arc welding torches, either water- or air-cooled, were used with a commercial 300-amp selenium-rectified welding power supply. Torch shielding was achieved through the use of ceramic gas cups from $^3/_8$ to $^5/_8$ in. diam. Argon and helium gas of 99.99% minimum inert-gas content were used. Argon was used for torch shielding, and helium was normally used as the backup gas. Tables 1 and 2 list the chemical and mechanical properties of the materials used.

Table 1—Chemical Certification of Stocks Used

Material	Form	C, %	N_2, %	H_2, ppm	Others, %
A-40	0.062- and 0.250-in. plate 0.062- and 0.093-in. wire	0.1	0.010	55	...
A-55	$2^1/_2$-in. Sched. 40 pipe	0.033	0.011	..	0.26 Al
A-40	0.062-in. wire 0.092-in. wire 0.125-in. wire	0.027	0.020	40	0.046 Fe
A-40	0.092-in. wire	0.02	0.007	99	0.18 Fe

Procedure

Root passes were evaluated on $^1/_{16}$ and $^3/_{32}$-in. A40 plate using no filler wire and various types of inserts and the results were compared with those obtained using hand-fed filler wire.[1] Fusion passes in A40 $^1/_4$-in. thick plate and A55 pipe, using beveled joint designs, were also studied in this investigation.

A $^1/_{16}$-in. thoriated-tungsten electrode was used in welding, holding a short arc, which produced approximately 10 to 12 v at welding currents of 30 to 80 amp.

Designs of the various inserts and joints used in this investigation are shown in Fig. 1. The root-pass welding technique consists of first placing the insert, which had been shaped to the proper geometry, in the space between the lands and positioning vertically. Backup gas is applied to the joint and maintained under positive pressure throughout the entire welding operation. In both pipe and plate, small tack welds spaced approximately $1^1/_2$ in. were made with low heat inputs of 20–30 amp. Without such tacks, the possibility of the insert buckling out of position during welding is increased. On pipes, counterposition welding was used, starting the bead on one tack and moving to an adjacent tack, then moving to a position approximately 180 deg. circumferentially and repeating the same procedure. Backup-gas pressure was reduced progressively as the root pass neared completion. No particular sequence of welding was necessary on plates.

Prior to making nonfiller-wire root passes on the pipe, tack welds were made at two opposite circumferential positions. No root gap was used in the preweld fit-up. A complete circumferential root pass may often be made in one operation, provided proper conditions exist to prevent overheating the base metal.

Table 2—Mechanical Properties of Stock

Material	Form	Tensile strength, psi	Yield strength, psi 0.2%	Elongation in 2i n., %	Other
A-40	0.062-in. plate	51,400	39,600	41.7	...
A-40	0.250-in. plate	47,800	33,500	39.2	...
A-55	$2^1/_2$-in. Sched. 40 pipe	80,600	58,200	28	...
A-40	0.062 and 0.092-in. wire	...	...	...	...
A-40	0.062-in. wire	71,000	49,000	42.5	51% reduction in area
	0.092-in. wire	74,100	52,000	33	52% reduction in area
	0.125-in. wire	72,000	48,100	40.5	56.5% reduction in area
A-40	0.092-in. wire	69,800	51,100	39	...

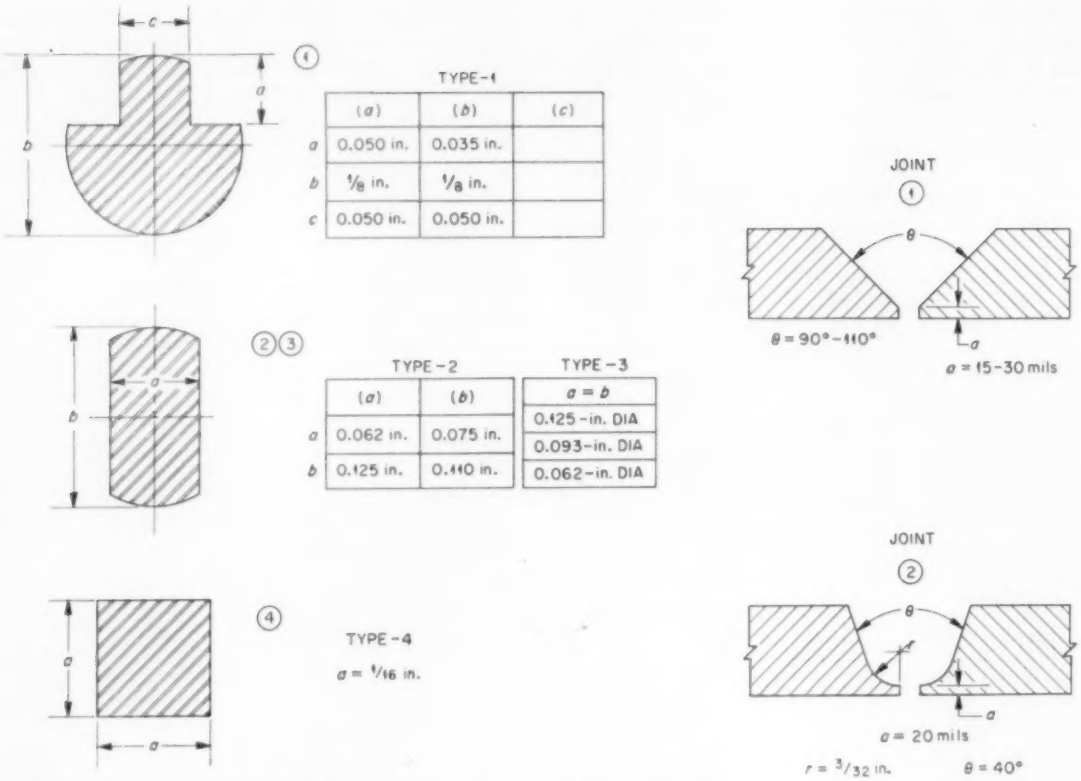


Fig. 1—Root insert and weld joint designs used for root pass welding investigation

Visual and radiographic inspection, transverse- and longitudinal-bend coupons, and metallographic examinations were made of single-pass welds. Several tensile coupons were made and compared to the mechanical properties of previous welds on the same materials made with manual filler-wire additions. These tests verified previous observations that insignificant mechanical property variations occurred over a moderate weld-metal hardness range.[1] Thus, metallographic examination was used for quality evaluation in the balance of the investigation rather than tensile coupon tests. Multipass welds in thicker sections were completed by hand-fed wire additions before bend tests were made. They were then tested the same as the single-pass welds. However, the metallographic evaluations of multipass welds were made on the root area and root surface.

Discussion

The characteristics of insert-type welding differ in several respects from filler-wire addition welding. In making the root pass using the latter technique, the welding heat required for a completely fused, full-penetration weld results in quite extensive breakdown of the land and push-through of the filler metal. In insert-type root passes, the melted insert tends to flow upwards, due to surface-tension forces, tending to decrease the size of the root reinforcement. Excess weld heat input in insert welds results in concave root surfaces, due to excessive metal flow. This condition is referred to as "suck back" and is normally not considered a desirable condition. Insufficient weld heat results in unfused or incompletely penetrated root passes.

Variations of joint or insert designs and backup-gas pressure are two important methods used to increase the range of welding heat input. The limitations on welding heat input for air welding titanium restricts the size land and inserts that can be satisfactorily melted and fused. The fit-up problem could be eased by using larger lands and inserts, but gas shielding under these welding conditions approaches the condition where use of trailer or enclosed dry-box equipment becomes mandatory. This situation would decrease the utility of inserts for field welding to a virtually impractical point.

One of the factors that allows the welder to have a relatively good visual indication of metal breakdown for regulating torch movement in stainless steel insert welding is the fact that the metal has a solidus-liquidus temperature range on melting; thus the

change of state from solid to liquid is not instantaneous. Commercial titanium, being essentially a pure metal, has practically no solidus-liquidus temperature range; hence practically instantaneous solid-to-liquid metal breakdown would be expected. With very little visual indication of metal breakdown, proper torch movement by the welder could become a difficult problem.

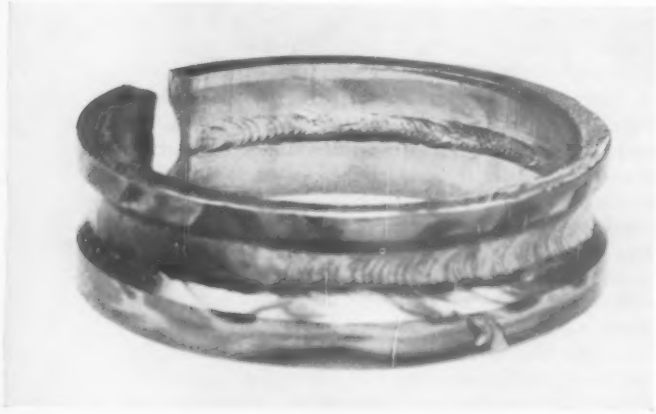
Data and Results

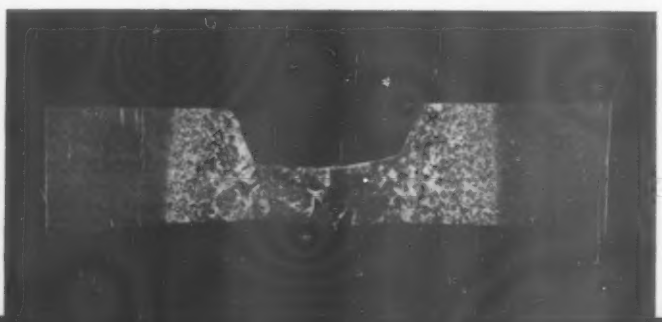
Fusion Root

If filler metal is not required in a root pass, a logical configuration for study, and especially for a field weld, would be a joint in which the lands are butted and the root pass made by simply fusing them together. Such a joint design is illustrated in Fig. 1, Joint 2, a J-beveled joint. With this configuration, proper fit-up prior to welding and alignment during welding are both simplified.

Satisfactory welds with a fusion root were made with welding currents of 30 to 35 amp with a head speed of 2 to 3 ipm on a 0.025-in. land. Land thicknesses of 0.040 in. were welded using a welding current approximately 50 amp with a 2 ipm travel speed which also produced satisfactory welds. The melting and breakdown of the lands during welding were quite easily detected by the welder; thus proper torch movement was not difficult. That successful welds may be made with such a configuration are shown by Fig. 2 which contains a photograph and macrophotograph of such a weld on $2^1/_2$-in. diam Schedule 40 pipe. The root contour was quite uniform along the entire length of the weld, being approximately flush with the inside diameter of the pipe. The root reinforcement geometry is not overly sensitive to changes in welding heat and backup-gas pressures. Joint offset of approximately 25% of land thickness may be tolerated with no apparent quality effect on the weld.

Fig. 2—Photograph and cross section macrophotograph of nonfiller-wire root pass with one filler pass illustrating uniform root surface. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF. X5





In a root pass where reinforcement is too heavy, the weld may be corrected with a re-fusing pass made at the same welding heat over the original pass, causing the metal on the root surface to pull up approximately flush with the base metal. No incompletely fused root passes were encountered in any welds of this type. Radiographs and metallographic examination of these types of welds showed completely fused, sound weldments with no porosity. The average microhardness, as seen in Table 3, was found to be approximately 10 DPH numbers greater in the weld metal of these types of welds than those made using hand-fed filler wire, indicating no significant contamination.

The use of this technique for making root passes in titanium fulfills all the original quality requirements of geometry, soundness and noncontamination in a weldment. The technique requires relatively simple preweld preparation and no greater welder skill requirements than normal manual filler-wire techniques.

Commercial Insert

A logical beginning in a study of titanium root inserts would appear to be the adaptation of a commercial stainless steel insert which had been used successfully and for which procedures had been qualified within the Laboratory. Inserts of this type were therefore machined from titanium wire to the same configuration recommended for stainless steel.[2] Using this size insert ($^5/_{16}$-in. diam lower section) with $^1/_8$-in. A40 plate and subsequently $2^1/_2$-in. Schedule 40 A55 pipe, root-pass weldments were made. The heat input necessary to properly break down the insert was found to be prohibitive for air welding titanium. A zone of high temperature extended a distance of almost an inch on either side of the weld, extending well into the base metal, exceeding the gas coverage ability for the largest gas cup. Base-metal discoloration indicated possible contamination. The face surface of the weld bead usually evidenced a rainbow-type film with a white powdery film often appearing. Metallographic examinations (visual and hardness transverses) confirm the extent of contamination indicated. Data in Table 3 summarize pertinent observations.

In an attempt to reduce the heat input, smaller type modified commercial inserts (1a and 1b in Fig. 1) were next evaluated. To secure proper flow of metal into the joint, the smaller insert requires more exact fit-up than does the larger. The maximum occurrence in this study of uneven and/or nonuniform root penetration was evident in the Type 1a and 1b inserts. Various modifications of height and diameter ratios were investigated with no marked

Table 3—Data on Root Passes Using Various Type Inserts

Insert type[a]	Joint design type[a]	Welding current, amp	Welding speed, ipm	Average weld micro-hardness DPH, 10 kg	Remarks
1 Commercial	1	120–140	1½	280	Discoloration, uneven pull-through in joint
1a Commercial	1	105–115	1	220	No reproducibility on pull-through in joint, slight contamination
1b Commercial	1	110–110	1½	210	No reproducibility on pull-through in joint, slight contamination
2a Elliptical	1	80–90	1½	210	Difficult to produce consistently uniform root, results in slight reinforcement
3 Circular 0.062-in.-diam	1	60–65	1½	200	Uniformly reproducible root, practically flush to base metal
4 Square	1	50–60	1½	180	Fine porosity at weld metal-base metal juncture, concave root uniform
Butt joint, no filler wire	2	30–50	2–3	195	Root flush to slight reinforcement of base metal, uniform
Filler wire	1, 2	50–60	1¼	185	Normally 0.020–0.050-in. root reinforcement

[a] See Fig. 1.

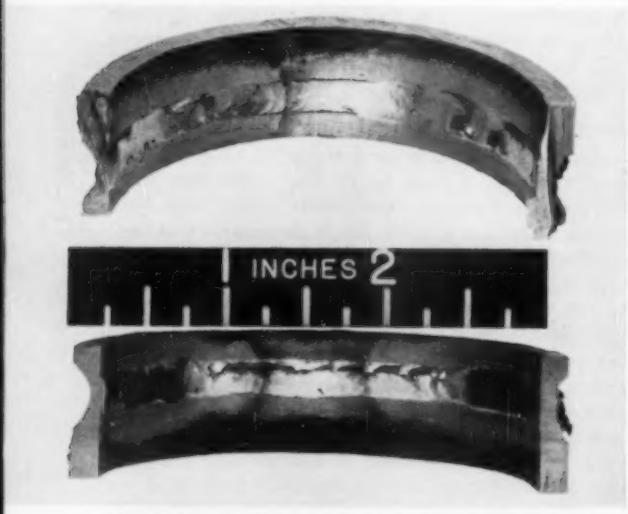


Fig. 3—Photograph of root pass illustrating nonuniformity using Type 1 root insert. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF

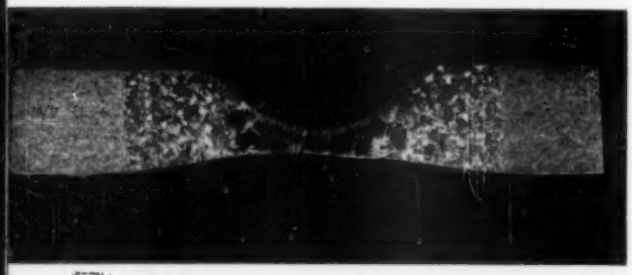


Fig. 4—Cross-section macrophotograph of weld using Type 1 root insert taken at a position of desirable geometry. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF. ×5

alleviation of any of the difficulties encountered using this type insert. The heat input required for the smaller inserts, although higher than that required for hand-fed wire, was not considered to be outside a range which could be adequately shielded to produce proper welds. Figures 3 and 4 illustrate root surfaces and a cross section of a Type 1a weld.

In stainless steel welding, at improperly fused positions, an insert of this type may be rewelded and properly fused. In titanium the same may be accomplished only if very little fusion has occurred at the position. If the insert has melted to some degree, a significant increase in welding-heat input is required for remelting because of increased heat-conduction requirements. This results in greater contamination at such a position. Serious porosity, usually located at the insert and land interface position, often occurs in improperly fused welds. A slight amount of porosity, detectable by radiography, will often occur at this location in welds which appear to be otherwise sound. Increasing the welding-heat input, at the risk of contamination, is one method of eliminating this porosity. Porosity occurring in the central portion of the weld is rarely encountered.

In these insert designs in which a surface contact is called for between the insert and the bottom or inner surface of the plate or pipe, the occurrence of a gap at this position increases the difficulty of securing satisfactory welds. Since the heat flow across this contact is apparently critical to the process, it is possible that any film present or formed during welding would alter heat conduction at this point. Titanium is particularly prone to surface-film formation; thus any air entrapped during fit-up would be available for film formation at the elevated temperature encountered during welding. It is obvious that mismatch on pipe internal diameter

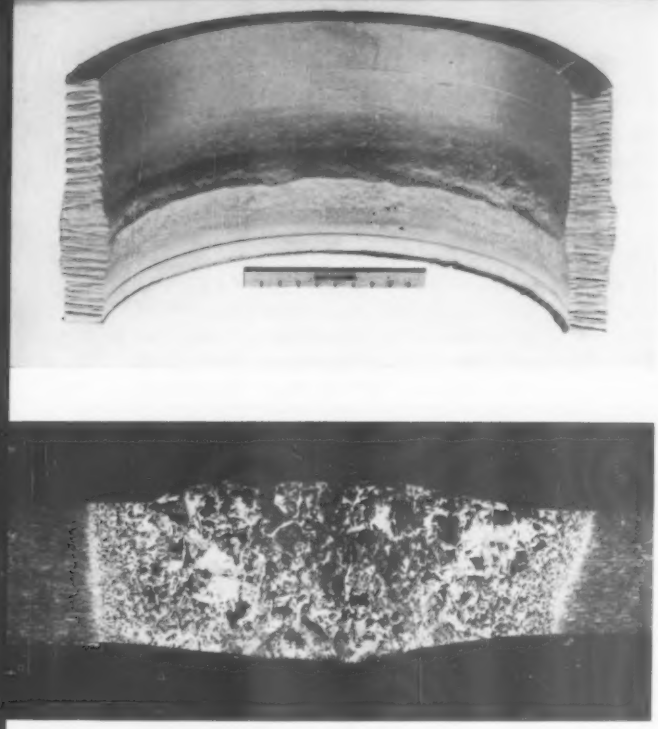


Fig. 5—Photograph and cross-section macrophotograph of weld illustrating quality obtained using Type 2 root insert. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF. X5.

increases the difficulty of tight insert fit-up on the inner pipe surface and favors the occurrence of bad welds.

The requirement of exact fit-up of the pipe internal diameter, the nonuniformity of the root pass along the length of the weld, and the comparatively greater contamination of the weld metal are distinct disadvantages encountered in the commercial-insert welding technique. The three advantages of this type insert over hand-fed wire in field welding other metals—namely, ease of welding, uniform root reinforcement, and ability to be re-fused—are largely lost in titanium weldments.

Elliptical Inserts

With the commercial inserts, most of the difficulties seemed to be caused by the relatively large mass of metal inside the pipe. Attempts were, therefore, made to study the effects of insert size and geometry. As a compromise between the straight fusion passes and the commercial inserts, elliptical-type root inserts, produced by flattening a circular wire to dimensions shown in Fig. 1 (Types 2a and 2b) were investigated. The welding-heat input was found to be only slightly greater than required for conventional welding. The insert melted uniformly and flowed up into the joint in a fairly satisfactory manner. The insert was usually placed so that the cross-section center (intersection of major and minor elliptical axes) coincided with the center position of the land. However, this insert may be moved up or down in joint fit-up. Varying the position of the center of the insert as much as 0.035 in. above to 0.020 in. below the land center had no marked influence on resultant weld geometry. Welds were made in which the pipe, i.e., or bottom surface of a plate, was offset as much as 0.020 in. with no great change in welding condition or geometry. Fit-up is relatively simple with this type insert. Insert breakdown was not as instantaneous as expected; thus it was possible for the welder to discern melting. However, this was a sufficiently great problem that torch movement to obtain uniform reinforcement required considerable welder skill. Hardness of the weldment area did not differ radically from normal hand-fed root passes, the hardness of the weld-metal and heat-affected base-metal zone being about 5 DPH greater than that of the parent plate, or 30 DPH greater than those made in a dry box.

The extent of root reinforcement was controlled by two methods: (1) backup-purge-gas flow and (2) welding-heat input. The reinforcement decreases with increase of these two parameters, the latter having the greatest effect. Too high a welding-heat input results in "suck back." It was found that as the wire was flattened to produce a more eccentric insert, welding became more difficult. Under these conditions, certain longitudinal positions in the weldment showed improper fusion, with the center of the weld not completely fused or pulled up (referred to as icicles). Uneven fusion across the weld in a transverse direction occurred less frequently. Often in welds improperly fused transversely, the center and one side would be properly fused while the other side did not completely fuse or pull up properly; also, the base-metal land on this side did not break down properly. Welding over improperly fused areas at the same welding heat completely fused the area, but root reinforcement was greater at these positions than the balance of the weld. Figure 5 is a photograph of the root surface and cross section of this type of weld showing nonuniform fusion of the base-metal walls.

Circular Inserts

Decreasing the ratio of the elliptical axes which alleviated the problems discussed above eventually brings one to a design ratio of unity, which is a circular cross-section insert. Round $^1/_{16}$, $^3/_{32}$ and $^1/_8$ in. diameter wire inserts were investigated in the same manner as the flattened insert. Very little difference in results was obtained with respect to consistency of weld geometry and hardness. The welding-heat input required was lower for round inserts than for flattened inserts of equal cross section. The longitudinal and transverse cross sections were of better uniformity with this insert. The breakdown of the metal as welding proceeded was quite discernible by the welder, thus facilitating proper torch movement. As the insert size is increased from $^1/_{16}$- to $^1/_8$-in. diameter, metal breakdown becomes more difficult to follow. The heat input required for properly fusing a $^1/_8$-in. diam insert exceeds the practicable limit for air-welding

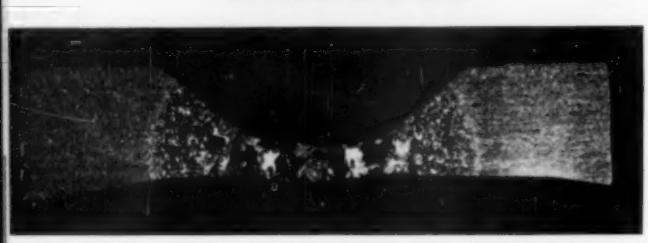


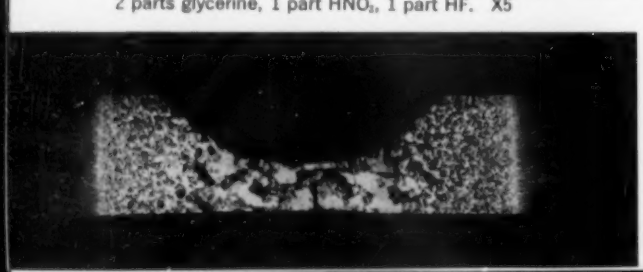
Fig. 6—Photograph and cross-section macrophotograph of weld illustrating quality obtained using Type 3 ($^3/_{16}$-in.) root insert. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF. X 5

shielding conditions. Although $^1/_{16}$- and $^3/_{32}$-in. diam inserts are both practicable, the smaller insert requires less heat input and thus is preferred.

The fit-up between a round wire and a 0.020-in. land is a line contact. Thus, the freedom of vertical movement is only 0.020 in. before the wire is theoretically no longer in contact with the land. Also, it is apparent that pipe offset must be less than 0.020 in. for the insert to have contact with both lands. (A practical limit of joint offset is about 0.015 in.) Sometimes a wire "pops out" at some position after one or more holding tacks have been made and must be repositioned before more tack welds are made. In actual practice this problem is alleviated by tamping the insert into position in a root gap slightly smaller than the insert diameter. This upsetting gives a small surface area contact rather than a line contact.

In pipe welding, backing purge gas (helium) is maintained inside the contact surface between the insert and the joint land. During welding, a small gap between insert and land often tends to form at a position just forward of the leading edge of the weld puddle. It is felt this gap is created as the insert fuses and loses contact with the land. Helium, being a light gas, tends to escape with considerable velocity. The fact that the gap is small tends to promote a high-velocity gas jet. Turbulence can also be minimized by close regulation of the gas flow through the torch. Using a low-welding-heat input often results in fine porosity at the edges of the weld where the insert and land were initially in contact. This is thought to be entrapped purge gas which was escaping through the gap when fused metal pulled up and sealed the gap. The metal then solidified before the itinerant gas could escape. Increasing the welding-heat input appeared to eliminate this porosity, which is consistent with the explanation of metal remaining molten for a time sufficient to permit entrapped gas to escape. The use of argon-gas backup rather than helium resulted in slightly less porosity. In welding over areas where the weld metal had not pulled up properly in the joint, it was found that this condition could be quite easily remedied. Figure 6 consists of photographs of a round-insert root-pass weld, showing root surface and weld cross section. The root reinforcement in this type weld is very slight, being practically flush, and is quite uniform along the total weld length. Metallographic examination of these root passes indicated a weld quality essentially equivalent to hand-fed root passes. The only discernible difference was a slight weld-metal-hardness increase in the insert weld. The average hardness, which was 15 DPH greater than the hand-fed welds, does not appear to have any practical significance in evaluating the usability of this technique for field welding. The close tolerance on joint preparation and limitations on joint offset in preweld fit-up are disadvantages for field welding.

Fig. 7—Macrophotograph of cross section of root pass made with Type 4 root insert illustrating concavity. Etchant: 2 parts glycerine, 1 part HNO_3, 1 part HF. X5



Square Insert

The use of a square cross-section insert for root-pass welding was also investigated. A $^1/_{16}$ in. square insert was used. The first weld was made on $^1/_8$-in. sheet using 40-amp current with welding speed of approximately $1^1/_4$ ipm.

The resultant bead appeared to be fully fused and quite uniform with very little root reinforcement. Radiographic inspection indicated continuous fine-to-medium line porosity along the length of the weld at the original juncture of the insert and the root faces. Very little porosity occurred in the central portion of the weld metal. Metallographic examination confirmed the presence of line porosity along both edges of the root pass. There was no definite hardness increase in the weld metal, indicating no contamination from air or metal oxide surface layers in the joint. It was noted that fusion may be obtained using a heat input approximately 30% lower than that required on a $^1/_{16}$-in. round insert. Additional welds made using this insert and the same welding amperage on $^1/_8$- and $^1/_{16}$-in. sheet, varying the purge-gas flow and welding-torch speed, resulted in decreased porosity but not to an acceptable extent. Very little decrease of welding speed was

possible without completely undesirable weld geometry resulting.

By increasing the welding current to 55 amp, a root face practically flush with the bottom plate surface was obtained. Fine-to-medium porosity occurred along the side of the weld at isolated positions. Increasing the welding current to 60 amp resulted in a weld containing much less porosity (acceptable); however, the root face was quite concave, indicating excessive "suck back." Figure 7 is a macrophotograph of the cross section of this weld. Rewelding this type insert at the initial welding heat has a marked effect on weld metal pull-up resulting in a decrease in the root reinforcement. However, little or no change in the initial porosity was noticed in an area which had been refused. The metallographic examination of these welds gave hardness results equivalent to hand-fed filler root passes. The problem of balancing the effect of welding-heat input versus "suck back" and porosity control to obtain flush root reinforcement is quite critical because of the pronounced effects over narrow ranges of the variables. Therefore, the use of this insert for single-pass field welds was not considered practical. In multipass field welding, it is possible to increase the root reinforcement by using adequate-penetration, manual, filler-wire passes directly over the root pass. Therefore, this technique for root passes can still be considered for multipass field welds.

Conclusion

A full-penetration, completely fused, flush root surface weldment with no significant contamination is the standard of weld quality desired in this study. An air-welding technique which consistently attains these objectives in an all-position titanium root pass with the minimum of welding difficulty was found to be the nonfiller-wire technique. The circular insert also produced a weld of essentially equal quality but presented difficulties in joint fit-up and welding. Techniques using inserts of other geometry failed to attain the desired objectives.

Manual filler-wire air welds are quite exacting in joint preparation and fit-up. A full-penetration, completely fused, uncontaminated root pass with uniformly flush root reinforcement is difficult to attain. Rewelding over unsatisfactory portions of the root pass within the imposed heat limitations does not result in decrease of weld reinforcement, which is characteristic of the nonfiller-wire techniques investigated.

The nonfiller-wire technique, using a butted joint, resulted in a root reinforcement practically flush with the base metal, along with completely fused lands. This condition was quite uniform along the total weld length. A weld hardness increase of 10 DPH numbers over manually added filler metal indicated no significant contamination.

Commercial-type inserts produced welds of nonuniform penetration and lack of fusion at numerous positions along the length. The greatest hardness due to air contamination was noted with this technique. Rewelding at improperly fused positions did not result in flush root reinforcement and did result in excessive contamination at those positions. The preweld fit-up requirements were most exacting using this technique. This technique fulfills none of the optimum weld requirements.

The use of flattened circular-wire or elliptical inserts did not meet the requirements of uniform root contour along the length of the weld. Positions of heavy root reinforcement or improper fusion could not be rectified by welding over that position. Greater difficulty in welding was experienced by the welder than is normally encountered in manual filler-wire-addition welding.

Circular root inserts had a tendency to promote porosity at the original land surface. The preweld fit-up is quite critical for this type insert. Flattening the insert slightly eliminated the porosity and alleviated the difficulty of fit-up to a minor extent. Apart from these difficulties, this technique produced root passes which met all other optimum weld requirements.

Square root inserts were found to result in porosity in the root pass. This condition could be remedied by use of slightly higher welding-heat input, which resulted in a concave root surface. The extent of root reinforcement was found to be quite sensitive to minor changes of welding variables. The control of the process was considered too critical for single-pass field welds. However, it still possesses some potential for use in multipass field welding where concavity can be corrected by the subsequent filler-wire passes. Other than concavity of the root pass, this technique produces welds of the required quality.

In special cases encountered in field welding, where accessibility or quite different dimensional work than that investigated is involved, circular, square or other type inserts such as flat washers, may well prove more desirable for the specific application than nonfiller butt-joint welding.

Even if the requirement of a flush root reinforcement is eliminated, the technique of using a butted joint with no filler metal would be recommended for all field welding in preference to the manual filler-wire addition technique. Such is not true with any of the inserts studied as the exacting preweld fit-ups place a severe handicap on such techniques.

Acknowledgment

The author wishes to express his indebtedness to G. M. Adamson of the Oak Ridge National Laboratory for timely and valuable comments on the work during progress, and for suggestions and review during the preparation of the manuscript.

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2. Risch, T. A., and Dohna, A. E., "Consumable Insert Method of Root Pass Welding," *Ibid.*, **33** (7), 670–679 (1954).

Practical Welder and Designer

All-Welded Aluminum Deck Housing for New Cargo Ships

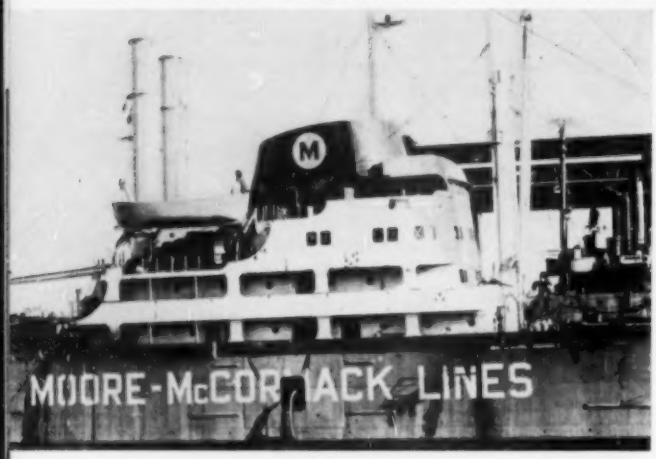


Fig. 1—Completed all-welded aluminum deck house and stack are shown in place on the SS *Mormaccape*. Use of aluminum permitted the deck house to be prefabricated in the shipyard platen area and reduced welding time by approximately two-thirds

Two of the first new ships in the Moore-McCormack Lines fleet to be equipped with all-welded aluminum deck houses and stacks were completed recently at Todd Shipyards Corp., Los Angeles Division, San Pedro, Calif. Both vessels, the SS *Mormaccape* and the SS *Mormacglen*, are 484 ft cargo-liners destined for service between Great Lakes ports and South America.

Welding of the 30-ton deck houses was done automatically, using the gas metal-arc process. Base alloys for the deck, bulkhead plating, beams, stringers and frames are aluminum Type 5052-H32 and Type 5083-H112. These grades were specified because of high-strength-to-low-weight ratios and good corrosion resistance properties. Alumar 5356 welding electrode wire was used in most of the operations.

Use of aluminum for the deck house and stack material offered three major advantages:

1. From an economic standpoint, aluminum

Based on a Story from the Arcos Corp., Philadelphia, Pa.

Fig. 2—Welder uses gas metal-arc torch to weld aluminum plate sections during fabrication of SS *Mormacglen* stack

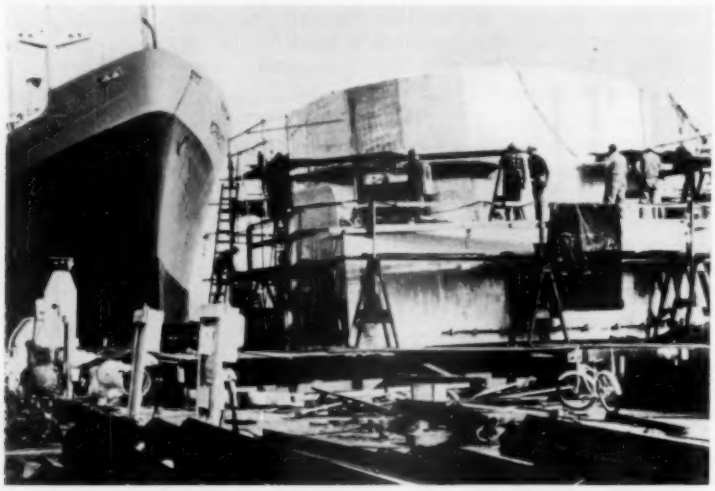


Fig. 3—Aluminum stack for SS *Mormacglen* is shown being welded at right; automatic welding equipment is visible on scaffolding

permitted a 3-to-1 weight saving over steel which results in increased payload capacity of each ship.

2. Stability of the ships is improved by lowering of the center of gravity. Decreased weight also results in fuel savings.

3. Welding time was approximately one-third of the time usually required to fabricate a steel deck house. Use of lighter weight aluminum permitted prefabrication of the deck houses in the shipyard platen area where automatic equipment could be put to work. If steel were used, the job would have required manual welding of a large number of pieces in position aboard the ships—a time consuming operation.

After each deck house was completed, it was lifted from the platen area by means of two 25-ton cranes and placed in position aboard the ship. Both vessels are primarily dry cargo vessels with facilities for 12 passengers and a crew complement of 60.

Hard-Surfacing Wards Off Wear During Roof Shingle Manufacture

During manufacture, the extremely sharp edges of roofing shingles can cut through steel guide plates in as little as two weeks. A small amount of cobalt-base alloy will increase the useful life of these guides by three to four times. Bird and Son, Inc., Charleston, S. C., now protects all guide plates to capitalize on the longer life.

The circular plates are hard-surfaced with about 1 lb of metal, deposited in a circumferential recess machined into the surface. The rod is applied by the oxyacetylene welding method to a depth of $^1/_8$ in. It is then machined to provide a flush surface.

This alloy is composed of 30% Cr, 12% W and about 56% Co. Carbon is held to $2^1/_2$%. It deposits with a hardness of Rockwell C 54.

The production of roofing shingles in this plant is a continuous process. The base material feeds off of a large roll of stock, through various treating and coating stages and into a machine which slices it into individual shingles. The roll advances rapidly and the guides help to keep it running true.

Guide plates are used in three areas of the production line. A set of 9 in. plates is used at the shaft ends of a sheet guide where "slating" is done. Here, colored quartz rock granules—sharp as glass—fall onto the prepared roofing paper. The edges of the continuous roll subject the guide plates to severe abrasion. Guide plates are spaced only $^1/_8$ in. wider than the roll itself. They keep the production running smoothly through this area.

A set of $10^1/_2$ in. and a set of 9-in. plates are installed on the roll winder in two locations. Another 9-in. set is mounted to a guide roll leading into the machine that cuts the sheet into shingles. This set of guide plates must remain stationary, taking the full attack of the razor-sharp edges. When the guides groove, they are repositioned to offer a new surface.

Thus, a critical wear problem was solved by the application of a relatively small amount of high-quality metal in a strategic location.

Based on a story from the Haynes Stellite Co., Div. of Union Carbide Corp., New York, N. Y.

Fig. 1—Master mechanic indicates location of guide plate in shingle cutter. Hard surfacing this plate will make it last four times longer in severely abrasive service

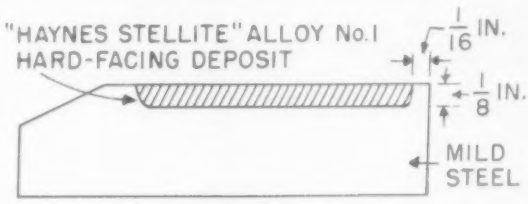


Fig. 2—Side view of typical guide plate

Skyline of Midtown Manhattan and the United Engineering Center (framed) as seen from over New York City's East River as airliner descends into LaGuardia Air Terminal

UNITED ENGINEERING CENTER

Panorama from the air

Pledges continue to move sections up the ladder to reach their goal. The majority of sections have attained 100% or more of their assigned quotas and have been placed on the Honor Roll. The last count shows AMERICAN WELDING SOCIETY pledges to be at 96% of goal.

Honor Sections

Section	Goal, %	Section	Goal, %
New Jersey	142	Bridgeport	105
Oklahoma City	138	Northwestern Pa.	105
Louisville	130	San Antonio	105
Mahoning Valley	121	Syracuse	105
Kansas City	120	Cincinnati	104
Worcester	120	Providence	104
Baton Rouge	119	Northern N. Y.	103
Birmingham	118	Chicago	102
Northwest	117	N. E. Tennessee	102
North Texas	115	Puget Sound	102
Hartford	114	Saginaw Valley	102
Wichita	113	Tulsa	102
Philadelphia	112	San Diego	101
Colorado	111	Chattanooga	100
Detroit	111	Eastern Illinois	100
Albuquerque	110	Houston	100
Dayton	110	Lehigh Valley	100
New Hampshire	110	Long Beach	100
Pascagoula	110	Los Angeles	100
Richmond	110	Madison-Beloit	100
Western Mass.	110	Michiana	100
Holston Valley	109	Mobile	100
New York	109	Nashville	100
Rochester	109	N. Central Ohio	100
St. Louis	109	Olean-Bradford	100
Boston	108	Pittsburgh	100
Long Island	108	Salt Lake City	100
Toledo	108	San Francisco	100
Iowa	107	Santa Clara Valley	100
Maryland	107	Stark Central	100
Niagara Frontier	107		
Sangamon Valley	107		

Pledges Needed to Meet Goal

Section	Needed	Section	Needed
Carolina	43	South Florida	330
Iowa-Illinois	90	New Orleans	350
Anthony Wayne	150	Susquehanna Valley	350
Shreveport	155	Peoria	365
Washington	180	York-Central Pa.	375
Arizona	200	Portland	385
Nebraska	200	Sabine	400
J. A. K.	235	Fox Valley	450
Orange County	275	Columbus	590
Western Michigan	280	Milwaukee	832
Indiana	287	Cleveland	900

Society News

Plans Proceed for Welding Exposition plus Full Program of Technical Papers, Tours and Other Activities at

43rd Annual Meeting in Cleveland

"Better Products Through Welding" is to be the theme of the Welding Exposition during the AWS 43rd Annual Meeting which will be held in Cleveland, Ohio, during April 9–13, 1962. The exposition will be held at the Cleveland Public Auditorium, April 10–12, and will feature the display and demonstration of the latest in equipment for welding as well as accessories and supplies.

The Sheraton Cleveland Hotel will be the site for a full program of technical papers and other activities, April 9–13. Present plans call for 24 sessions of technical papers, several to be sponsored by the ASME and one to be sponsored by the RWMA.

Cleveland Participation

An unusual feature of the technical program will be the sponsorship of one session of three papers on gas-shielded-arc welding by the Cleveland Section on the afternoon of April 9. During the evening of the same day, the Cleveland Section will hold its annual dinner party.

Cleveland is a hub of intense industrial activity and this is reflected in the many technical papers which will be presented. Offerings include papers discussing the latest welding developments in numerous fields ranging from aircraft and missiles to weld design and process evaluation. Among the sessions which will prove unusually interesting are those dealing with cutting, piping and the welding of structural steels.

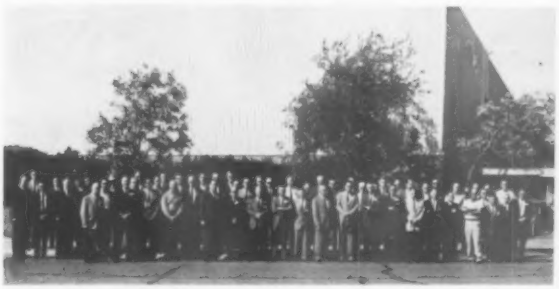
Guest Lecturers

The 43rd Annual Meeting will formally get under way during the morning of April 9 in Hotel Sheraton Cleveland and the opening, as in previous years, will feature the Adams Memorial Lecture—this year to be given by R. E. Lorentz, Jr., of Combustion Engineering, Inc. Beginning the following afternoon, Dr. Robert C. McMaster, Professor of Welding Engineering, Ohio State University, will deliver the 1962 Educational Lecture Series.

Robert C. McMaster

The Educational Lecture Series

FALL MEETING PLANT TOUR



A plant tour was one of the many high points of the recent AWS National Fall Meeting in Dallas, Tex. Trips were made to the Convair Division of the General Dynamics Corp. in Fort Worth as shown above and to the Gardner-Denver Co. in Dallas

J. C. Collins (center) of the North Texas Section was one of several tour hosts at Convair where visitors witnessed various welding and brazing processes used in fabrication of the frames for the B-58 bomber. Visitors also witnessed the gas tungsten-arc cutting of aluminum wing slugs for the B-58

has become a feature of the Annual AWS Meetings, and each year the Educational Activities Committee of the Society selects a subject and an outstanding figure in science or engineering to prepare a two part lecture. "Nondestructive Testing of Weldments," was the subject chosen for 1962 and McMaster unanimously elected as one of the greatest authorities in the country on this testing method. The subject is particularly appropriate because the Society for Nondestructive Testing is holding its Annual Meeting in conjunction with the AWS Annual Meeting. The lectures will be presented at 4:30 P.M. on April 9 and 10, at the Sheraton Cleveland Hotel.

Professor McMaster has been associated with nondestructive test development for a period of 18 years. He has supervised research in the nondestructive testing field at the California Institute of Technology; associated with Battelle Memorial Institute in the development of nondestructive testing techniques and taught the subject at Ohio State University for the last 6 years. He is past president of the Society for Nondestructive Testing; was editor of the SNT Nondestructive Testing Handbook and has authored many articles on X-ray, fluoroscopy, ultrasonics and other forms of nondestructive testing.

Other Activities

The Cleveland meeting will feature other activities such unusually worthwhile plant tours and a sparkling full program for the ladies. Details will be announced at a later date and the tentative program of the various technical-paper sessions will be published in the January 1962 issue of the WELDING JOURNAL.

National Officers for 1962–63 Nominated by AWS

Twelve members of the AMERICAN WELDING SOCIETY have been nominated to serve as national officers for the 1962–63 term. The National Nominating Committee, following careful study and deliberation, has submitted a select list of candidates for the approval of members. In accordance with National Bylaw requirements, ballots will be mailed to the AWS membership on or before Dec. 26, 1961 and must be returned by Jan. 26, 1962, to be valid for counting.

The committee which was given this important assignment was composed of a chairman, three members-at-large and eleven district representatives. Members of the committee were picked to reflect the interests of all geographic and industry groups of members.

Heading the list of nominees for the coming fiscal year is John H. Blankenbuehler of the Hobart Brothers Co. He has been nominated for the post of National President. Three vice presidents have been nominated to serve with Mr. Blankenbuehler. They are Clarence E. Jackson, Jay Bland and F. G. Singleton. Directors-at-large who have been nominated for 1962–65 are C. B. Robinson, R. H. Hoeffler, A. R. Meyer, as well as T. S. Long—and, finally, the various District Nominating Committees made up of representatives from each of the SOCIETY'S eleven districts have selected three men to serve as District Directors for the coming fiscal year. They are J. H. Matheny, A. W. Brown and W. H. Greer.

The chairman of this year's Nominating Committee was Past-President R. D. Thomas, Jr., who was helped greatly by eleven district representatives and three members-at-large.

Nominated for President

John H. Blankenbuehler

John H. Blankenbuehler was born in Elizabeth, Pa., and graduated from Lehigh University with a de-

John H. Blankenbuehler

gree of Electrical Engineer. He was employed at the Westinghouse Electric Corp., in Pittsburgh, for 23 years, starting as a design engineer. He was manager of welding apparatus engineering, in charge of all engineering on motor generator sets, transformer welders, automatic welding equipment and welding accessories at the time he left Westinghouse in 1946. Since then he has worked for Hobart Brothers Co., in Troy, Ohio, as design engineer.

Mr. Blankenbuehler has 34 patents on welding apparatus. He is a member of the honorary engineering society, Tau Beta Pi and honorary military society, Scabbard and Blade and is also a Fellow in the American Institute of Electrical Engineers.

A member of the American Ordnance Association, American Society for Metals, the Ohio Society of Professional Engineers, a registered Professional Engineer in Pennsylvania and Ohio. He is also active in the Troy Rotary Club.

During World War II he received a Certificate of Commendation from the United States Navy for electrical design work done for the Navy. He has presented a number of papers before various sections of the AIEE and AWS. A past chairman and secretary of the Dayton Section of the AWS, he served from 1952 to 1959 as a national director. His past offices include membership on the Technical Papers Committee. He was chairman of the committee that wrote Chapter 30 on Arc Welding Equipment of the Fourth Edition of the WELDING HANDBOOK. He is now a vice president of the AWS and was chairman of the District Council for the year 1960–61.

Mr. Blankenbuehler is presently serving on the Executive and Finance Committee, as chairman on the Technical Council, on the Honorary Membership Committee, the Office Assignment Committee, the Member Classes Voting Committee as chairman, the Membership Activities Committee and the Welding Handbook Committee.

Nominated for Vice President

Clarence E. Jackson

Clarence E. Jackson was born in Graceville, Minn. He graduated from Carleton College with honors in physics in 1927 and engaged in graduate work at George Washington University. Upon completing his studies, he joined the National Bureau of Standards.

Mr. Jackson was associated with the following branches of the government: Metallurgy Division, National Bureau of Standards (1930–36); U. S. Naval Gun Factory, Metallurgy and Testing Division (1936–37); and Naval Research Laboratory (1937–46). In 1946, he accepted a position at the Metals Research Laboratories of Union Carbide Corp., and in 1956 was made manager of their welding group.

In 1957, Mr. Jackson was transferred to the Development Laboratory of the Linde Co., at Newark, N. J. He is now associate manager of Electric Welding Development.

Mr. Jackson's AWS activities include: director for District No. 3 (1953–56); past chairman of the Washington, D. C., and Niagara Frontier Sections; Educational Activities Committee of which he is a past chairman; past chairman of Publications and Promotion Council, and a National Vice President. He is presently on the Executive and Finance Committee, the Districts Council as chairman, the Honorary Membership Committee, the Office Assignment Committee, and the Technical Papers Committee. Mr. Jackson was a representative on Mission 250 of the Organization of European Economic Cooperation in 1955, in Europe, under the sponsorship of the Welding Research Council and Ship Structures Committee. He has been active on a number of committees of the Welding Research Council, particularly those which pertain to weldability and interpretive reports. Mr. Jackson has presented numerous talks before various sections, and has authored more than 30 papers on welding and metallurgy.

Mr. Jackson was given the Distinguished Civilian Service Award in 1945 by the Secretary of the Navy. He also received the Samuel Wylie Miller Memorial Medal in 1956 and delivered the Adams Memorial Lecture in April 1959.

Nominated for Vice President

Jay Bland

Jay Bland graduated from the University of Rochester with a B.S. in Chemical Engineering in 1933 with the highest distinction in his class. After earning his M.S. in Metallurgy at Columbia University in 1934, he began employment with the Sun Oil Co. at Marcus Hook, Pa. In 1939 he entered the N. Y. Naval Shipyard and served as welding section head, continuing in this post until 1951. He then became head of the Metals and Welding Section, Engineering Research Dept. of Standard Oil Co. of Indiana. From 1958 to date he has been employed as manager, Welding Development at the General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N. Y.

Mr. Bland has been an active member of AWS, having served in the following capacities: (past) chairman of the Chicago Section; director-at-large on the board of directors; member-at-large of the National Nominating Committee; and chairman of the Committee on Awards. He has been author or coauthor of many technical papers covering welding and inspection and has addressed several AWS sections on these subjects. A member of the committee that prepared the section on inspection in the WELDING HANDBOOK, he was also chairman of the committee that wrote the chapter on filler methods in the Fourth Edition. In 1956 he won the Lincoln Gold Medal.

AWS activities on the part of Mr. Bland now include the Executive and Finance Committee, chairmanship of the Publications and Promotion Council, Honorary Membership Committee and the Office Assignment Committee.

Among his other affiliations are ASM, SNT, Phi Beta Kappa, Sigma Xi, the Metal Science Club (N. Y.) and several technical committees of the Welding Research Council.

Nominated for Vice President

F. G. Singleton

Born 45 years ago, Mr. Singleton is today the father of seven children. A graduate of the University of Kansas City, Mr. Singleton first worked for the General Motors Corp. and rose to the position of superintendent of the Body Shop. With the advent of World War II, he served with the U. S. Army Air Force and, as Lieutenant Colonel, was a squadron commander in the European Theatre Operations. After the termination of hostilities, Mr. Singleton joined Trans World Airlines as an assistant chief test pilot and, in 1955, left to go into the welding business. He is now president of the Singleton Welding Supply Co. in Kansas City, Mo.

Mr. Singleton's AWS activities include, past chairman, vice-chairman, treasurer, secretary program chairman and director of the Kansas City Section. On a national level, he served as chairman of the Annual Meeting held in 1955 and was a district director for two terms and director-at-large for two terms. Mr.

Singleton has served on the National Finance Committee, National Nominating Committee, Section Officers' Committee, Publications Committee, Membership Committee, Building Committee for United Engineering Building and numerous other committees.

Nominated for Director-at-large 1962–65

C. B. Robinson

Mr. Robinson was born in Philadelphia, Pa., in 1906. He is a graduate of the University of California. From 1939 to 1944 he was employed by the Mare Island Shipyard in the capacity of welding engineer. He became associated with Air Reduction Pacific Co. as welding service engineer in 1944 and, in 1950, became supervising welding engineer in charge of process engineering.

He has been a member of AWS for over 30 years, serving on many committees both local and national. In this respect, he has served as technical chairman of the San Francisco Section and was district director of District 11.

Mr. Robinson is a member of the ASM, ASME, Navy League of the United States and the American Ordnance Association.

Nominated for Director-at-large 1962–65

R. H. Hoefler

After studying at both the Case Institute of Technology in Cleveland, Ohio and at the University of Maryland, Baltimore, Md., Mr. Hoefler worked for three years at the Cleveland Welding Co. in Cleveland, Ohio, as an assistant metallurgist before becoming chief metallurgist in 1948 for the Phelps-Dodge Copper Products Co., Los Angeles, Calif. In 1950, he returned to Cleveland where he joined the Brush Beryllium Co. as a staff engineer and where he continued in this capacity until 1953 when he became associated with Kaighin & Hughes, Inc., Toledo, Ohio. He has since remained with Kaighin & Hughes where he is presently chief welding engineer. From 1953-59 he also served as an evening instructor at the University of Toledo where he taught a course in "Welding Engineering and Practice."

Mr. Hoefler has been extremely active in AWS, serving as secretary for the Toledo Section from 1954 to 1956 and was chairman in 1958–59. He is presently a district director for District 6 and is a member of the National Board of Directors. During April 1960, Mr. Hoefler was presented with the AWS Meritorious Certificate Award.

The affiliations of Mr. Hoefler include the ASME and he is a member of the State of Ohio Piping Code Advisory Committee. He has served in an advisory capacity on state and national pipefitter-welder apprenticeship contests. In 1958 the Toledo Technical Council presented a citation to Mr. Hoefler as an engineer of the year. He has spoken before numerous AWS as well as ASME sections and has authored six technical papers in different publications.

Nominated for Director-at-large 1962–65

Amel R. Meyer

Mr. Meyer has been associated with the welding industry for 28 years in varying capacities and is presently with the Research and Development Dept., Whiting Laboratories, American Oil Co., in Whiting, Ind. He has been a member of AWS since 1941 and became affiliated with the Buffalo Section prior to serving with the Columbus Section from 1944 to 1949 when he became a member of the Chicago Section. He is a past chairman of the Chicago Section and, in 1955, was chairman of the Chicago Convention and Arrangements Committee. On a national level, he presently holds membership in AWS and ASTM subcommittees on filler metals for submerged-arc welding and is also on Welding Handbook chapter committees concerned with the welding of clad metals and the welding of field storage tanks. Likewise, Mr. Meyer is active on the WRC Interpretive Reports Committee as well as in the PVRC Materials Division.

In 1961 Mr. Meyer received the AWS Meritorious Award for the 7th District. He is a graduate of Ohio State University where he received a B.S. degree in welding engineering.

Plan now to attend the 43rd Annual Meeting and Welding Exposition in Cleveland, Ohio, during the week of April 9-13, 1962

Nominated for Director-at-large 1962–65

T. S. Long

Mr. Long has been affiliated with the resistance welding industry for many years and is presently president of the Taylor-Winfield Corp., Warren, Ohio. His AWS activities include membership on the Exposition Committee since 1954 where he served as chairman from 1956 to 1959. He has also been on the Manufacturer's Committee since 1958 and has been chairman since 1959. He has likewise been serving on the Reserve Funds Committee since 1957 and was reappointed and accepted membership on the 1961–62 Exposition Committee.

Nominated for District Director 1962–65

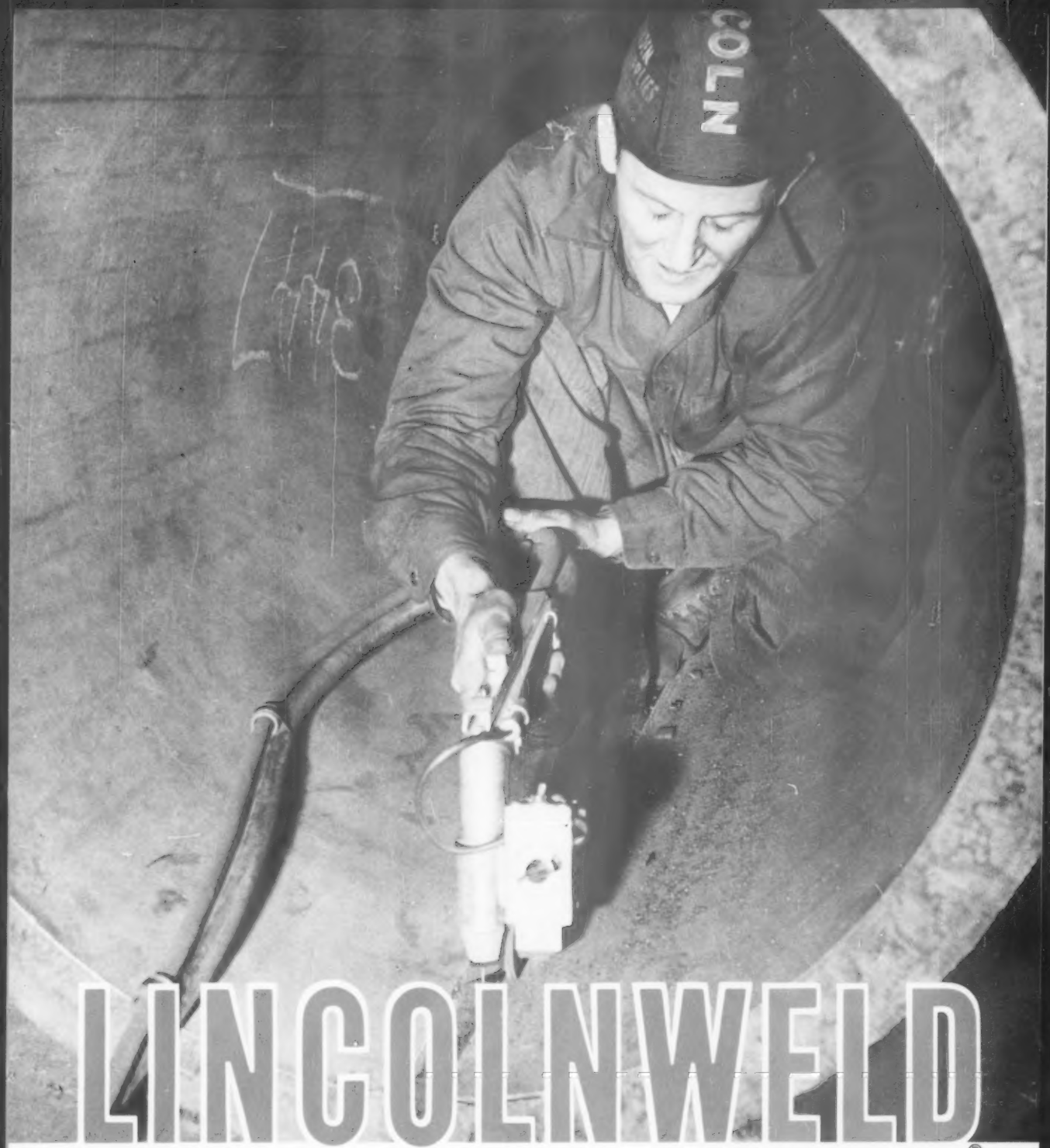
James H. Matheny
District 6, Central

James H. Matheny has been actively engaged in welding for the past 33 years and an active member of the AWS for 26 years. Born in West Virginia in 1912, his formal education was completed in night schools, including aeronautical engineering at the Maryland Institute of Technology and Temple University where he graduated in 1938 from the School of Metallurgy.

From 1928 to 1936, he held various positions with various aircraft companies after serving an apprenticeship with the Fokker Aircraft Co. For the next ten years, he was employed at the Bureau of Aeronautics—Naval Aircraft Factory in supervisory, engineering and management positions; here he developed techniques to produce the first all resistance welded military aircraft. From this experience, our present day MIL resistance welding specifications were established. Also during this period, an extensive program was directed to train military and civilian welding operators.

After termination of the war, he joined the Special Products Division

For details, circle No. 8 on Reader Information Card →



LINCOLNWELD®

Dilemma! What do you do when complex parts or short production runs limit you to a manual welding process . . . yet where your product's design and end use clearly require deep penetration and X-ray quality welds at highest speeds? Solution. Use **Manual Lincolnweld** submerged arc welders. The next few pages show how your competitors put these to profitable use. Want to see how? Turn the page.

These are MANUAL LINCOLNWELD "Squirt"® welders on the job

Operator welding this heavy machine base demonstrates versatility of ML-2 equipment. This process is particularly outstanding for getting high speeds and deep penetration on positioned fillet welds. Many use ML-2 as hand-held process but with work revolving beneath the gun on rotating, turntable positioner.

Continuous ¼-inch fillet welds in this hopper are made with ML-3 equipment at the rate of 32 inches a minute. Serrated wheel resting on work drives the gun at pre-set speeds. Flux and wire are fed into work at pre-determined rates. You get degree of control over finished welds simply not attainable by hand methods.

What does submerged arc welding have that manual welding doesn't? Basically, this. You can use much higher currents which result in proportionately higher deposition rates. These, in turn, result in higher production speeds, lower costs. Fewer pre-weld operations such as plate beveling are needed, and less metal is needed in the joint because of its inherent high penetration. Because welding current and arc length are both controlled automatically, you get consistently fine welds time after time. And, with the weld totally enveloped in flux, there simply is no spatter. Result? Better-looking welds that require few, if any, post-welding operations. All these factors translate into a long-term ability to produce quality products, at higher speeds, with lower costs.

Lincoln makes two models of "Squirt" Welders for hand-held submerged arc welding. One is the ML-2, the other, the ML-3. Both units have continuous wire feed and use granular flux. Essential difference between the two is that the ML-2 holds enough flux in its gun for about 10 feet of weld, while the ML-3 has flux fed through a tube to the gun and so can weld indefinitely without stopping. In addition, the ML-3 gun can be equipped with small travel unit having a serrated wheel which drives the gun at pre-set speeds along the work. This removes travel speed as an operational variable and leaves only directional guidance up to the operator. Both can be used in conjunction with either positioners or simple fixtures in order to remove that last variable, direction control.

LINCOLN WELDERS

Lincolnweld "Squirt" Welders can be utilized to do a variety of jobs whether used as completely manual equipment or in highly automated and fixtured set-ups. And, because you have relatively low initial capital investment, you are not committed to any particular type of production, process or product. In other words, your production lines can stay flexible, adaptable to changing product needs.

Contact your nearest Lincoln field engineer . . . a specialist in welding. Let him show you how you can put this flexible, versatile equipment to work increasing production and quality in your plant, shop or factory. Why not do it now?

Here, compact ML-2 gun fits into confined areas inaccessible to full-automatic equipment. While this process is not as fast as the full-automatic, it is considerably lower in installation costs; but most important, it is faster and more economical than stick welding where you require deep penetration at highest speeds.

Custom welding tasks such as this can be done best with ML-2 equipment fitted with new continuous flux feed attachment. As soon as this job is done, equipment can be switched to production of entirely different kind of task. Operators like the submerged arc because there is no flash, no need for headshield. Job is cooler, easier to follow.

Put one of these . . .

MANUAL LINCOLNWELD

Submerged Arc Welders to work for you

ML-2 "SQUIRT" WELDER

Total machine consists of wire reel case, control box with wire feed motor, welding gun and necessary cables. Current is supplied by a separate power source. Wire feeding mechanism is governed by a simple voltage control that maintains a constant arc length between electrode and the work by controlling wire feed speed.

Variations in arc length caused by manual handling are compensated for automatically. For more information about ML-2, ask for bulletin 5204.1.

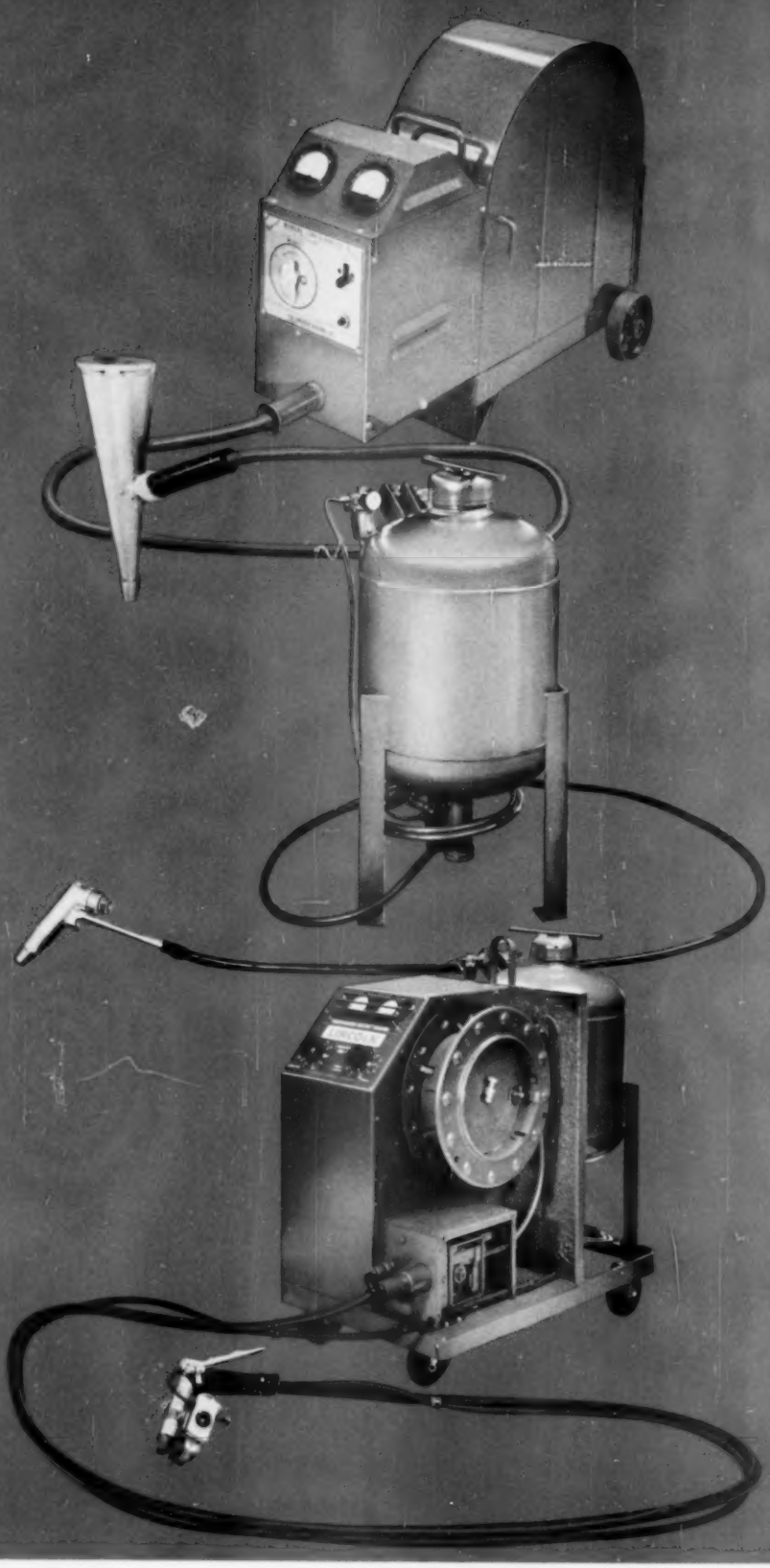
CONTINUOUS FLUX FEED ATTACHMENT FOR ML-2 WELDER

New special welding gun and flux tank provide a continuous flux feed system for ML-2 (or old ML-1) welders. Adds to their versatility, saves time, improves work quality since operator does not have to stop periodically to fill flux hopper. New gun, which fits to ML-2 handle, lets operator get into confined areas easier and at same time, keep gun better aligned over the work.

ML-3 "MECHANIZED SQUIRT" WELDER

Unit furnished complete with gun, cables and welder which incorporates wire feed motor, arc voltage and inching speed controls, ammeter and voltmeter which allow precise settings. Gun itself incorporates serrated drive wheel, speed control and travel reversing switch which lets operator weld in either direction according to the dictates of the job. Single press bar and trigger apply welding current, activate travel motor, electrode feed, and flux valve.

FOR MORE INFORMATION on Lincolnweld ML-3 equipment, request bulletin 5206.1 from your local field engineer. Or, if you prefer, write direct to the factory. Your request will be handled by return mail.



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The World's Largest Manufacturer of Arc Welding Equipment and Electrodes

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of the ITE Circuit Breaker Co., as research and development engineer, to develop processes and techniques to produce jet engine components. The duties of this position involved development work on resistance, submerged-arc, the gas-shielded and metallic arc welding processes and equipment, primarily on high-temperature alloys.

In 1952, he accepted a position as manager of assembly processes with RCA, Camden, N. J. The duties of this position involved the supervision of industrial and welding engineers in the fabrication of electronic equipment and as welding consultant with the various engineering groups.

Since January 1957, he has been employed by Clark Bros. Co., Div. of Dresser Industries, as welding engineer, reporting to the vice president, research and engineering. The duties of this position are to plan and create design criteria for weldments, plan and provide basis for welding specifications and to act as consultant from the welding metallurgical viewpoint.

Nominated for District Director 1962–65

Arthur W. Brown

District 6, Central

Associated with the Brown Hutchinson Iron Works in Detroit, Mich., since 1933 where he began as a shop helper, Mr. Brown has since steadily risen through the ranks. In this respect, he worked with steel erection crews before engaging in bookkeeping and cost work and in 1943–46 he was shop superintendent prior to a further promotion in the engineering department from which he proceeded into purchasing and sales. In 1955, Mr. Brown was appointed general manager and vice president for the company.

Mr. Brown has been active in the Detroit Section ever since 1948. Here he served on the executive committee and was an assistant secretary before becoming vice chairman. He was chairman during 1960–61.

Nominated for District Director 1962–65

W. H. Greer

District 9, Southwest

W. H. GREER is vice president and division manager of Southwestern Laboratories, an engineering inspection and testing organization which he joined in 1936. He had his formal education in engineering and during 1932–36 was employed with field parties on land surveys in Falls County.

During World War II, Mr. Greer served for three years as flight instructor with the Navy in the primary training command and as commanding officer of a mobile training detachment on light bombers. Following separation from the service in 1945 he returned to Southwestern Laboratories.

Mr. Greer is a past chairman of the Houston Section, having been an AWS member since 1939. He has served on both local and national committees of AWS. He was chairman of a committee that made recommendations relating to welding in preparation of the City of Houston building code and has had technical supervision of fabrication, erection and welding of many structures in this area.

He is past chairman of the Texas Chapter of the American Society for Metals, a district director of the American Society for Testing Materials and a member of the Engineers Council of Houston.

District Representatives Selected for the National Nominating Committee

Eleven nominees to serve the 1962–63 term as district representatives on the National Nominating Committee have been selected. Their names and addresses are listed as follows:

District No.	*Nominee*
1	Helmut Thielsch, Grinnell Corp., 260 W. Exchange St., Providence 1, R. I.
2	Robert A. Bartholomew, Lehigh Structural Steel Co., Allentown, Pa.
3	Harold Collins, Ring Manufacturing Dept., Dresser Manufacturing Co., Bradford, Pa.
4	Peter Patriarca, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn.
5	Randall G. Gilliss, 6051 Salem Road, Cincinnati 30, Ohio
6	Herman N. Werschky, National Welding Supply, G-5075 North Dort Highway, Flint 5, Mich.
7	A. C. Mulder, Miller Electric Manufacturing Co., Inc., P. O. Box 798, Appleton, Wisc.
8	Norman C. Qualey, Northern Ordnance Inc., Columbia Heights P. O., Minneapolis 21, Minn.
9	Clifton L. Moss, III, Wyatt Industries, Inc., P. O. Box 5418, Dallas 22, Tex.
10	John B. Wiley, Wiley Welding Sales, Inc., 840 East 60 St., Los Angeles, Calif.
11	Adolph M. Hubbard, Atomic Products Div., General Electric Co., 2151 South First St., San Jose 12, Calif.

AWS DIRECTORS-AT-LARGE

Term Expires	1962	1963	1964
	W. H. Hobart	R. B. McCauley	J. E. Dato
	F. G. Singleton	John Mikulak	A. N. Kugler
	C. B. Smith	E. F. Nippes	T. E. Jones
	J. R. Stitt	R. D. Stout	E. C. Miller

AWS DISTRICT DIRECTORS

District No. 1•New England	G. W. Kirkley	District No. 6•Central	R. H. Hoefler
District No. 2•Middle Eastern	C. L. Kreidler	District No. 7•West Central	L. L. Baugh
District No. 3•North Central	J. W. Kehoe	District No. 8•Midwest	G. O. Bland
District No. 4•Southeast	J. M. Shilstone	District No. 9•Southwest	C. L. Moss, III
District No. 5•East Central	P. J. Rieppel	District No. 10•Western	D. P. O'Connor
		District No. 11•Northwest	W. J. Erichsen

AWS PAST-PRESIDENT DIRECTORS

R. D. Thomas, Jr. C. I. MacGuffie

KEEPING YOU POSTED

By Fred L. Plummer

● President A. F. Chouinard in his opening address at the National Fall Meeting predicted a new era for welding together with a new era of service of the AMERICAN WELDING SOCIETY to the welding industry. Arriving at the Dallas airport on September 23rd, President and Mrs. Chouinard were greeted by representatives of the city, convention bureau and our North Texas Section, together with radio and television crews. Firmly established as a "Texan" by the presentation of a "ten gallon hat," President Chouinard gave interviews which formed parts of both radio and television broadcasts that evening and helped alert residents of the area to the following week of AWS activities. A police escort conducted President and Mrs. Chouinard together with your Secretary and Mrs. Plummer to the Hotel Adolphus (with a minor detour through the Baker Hotel).

● National Officers were guests of the North Texas Section at a delightful dinner dance held at the Dallas Country Club the next evening, following the traditional luncheon for members of the local arrangements committee held that noon in the Hotel Adolphus. Director C. L. Moss, III, was chairman of this group which came up with an outstanding performance in planning and conducting a fine ladies' program, the plant tours and the well attended and thoroughly enjoyed "Western Extravaganza" barbecue, and in assisting headquarters staff members in connection with all other convention activities.

● Mr. Robert B. Demoret, Chief of the Astronautics Section of The Martin Co. presented the keynote address "Space—Its Potential and Its Problems" following brief remarks by AEC Welding Forum Chairman Frank W. Davis, SNT Director Bryant E. Justice and WRC Director Kenneth H. Koopman, speaking for their respective organizations which co-sponsored some of the technical sessions.

● National Officers Chouinard, J. Bland, Blankenbuehler and Rockefeller as well as Past-Presidents Thomas, MacGuffie and Chyle were kept busy with Board, Council and Committee Meetings. National Membership Chairman Axtell chairmaned a meeting of MAC and attended meetings of the District Council and the Board of Directors. Staff members in charge of meeting activities included Fenton, Hall, Krisman, Mooney, Phillips and Schoonmaker. Directors, in addition to those named above, who attended the meeting of the Board of Directors included G. O. Bland, Dato, Hobart, Hoefler, Jones, Kehoe, Kirkley, Kugler, McCauley, Mikulak, Miller, Moss, Nippes, Shilstone, Singleton, Stitt and Stout.

● Both the Educational Open Meeting and the Section Publicity and Promotion Open Meeting were well attended and provided detailed and complete information and guidance in these activities for Section representatives. These and other activities at this very successful meeting are discussed more fully elsewhere in the JOURNAL. Future National Fall Meetings are scheduled as follows: Milwaukee, Oct. 1–4, 1962; Boston, Sept. 30–Oct. 3, 1963; 1964 San Francisco.

● Following these activities in Dallas, President Chouinard and your Secretary joined members of the Oklahoma City Section for a meeting on October 2nd at which Chairman Ralph E. McDermott and Program Chairman John Sherman presided with the assistance of Officers Wedel, Stephens, Fiegener, Barnes and Sampson. President Chouinard presented an excellent discussion of "Some Aspects of Flame Cutting" which was followed by a spirited question period. Your Secretary spoke briefly and exhibited the movie with sound showing the 1961 Welding Exposition held in the New York Coliseum. NCG Division of Chemetron District Manager J. W. Hunt provided transportation in Oklahoma City and also from there to Tulsa for a meeting the next night.

● At the meeting of the Tulsa Section your Secretary again presented the exposition movie and President Chouinard gave a "Progress Report on the Flux-Cored CO_2 Process." Chairman Duane G. Ellis presided at this enthusiastic meeting. Officers McWilliams and Fairless together with committee chairmen Huey, Duerr, Glenn and Johnson as well as many members of the Section Board of Directors participated in this excellent meeting at which Chairman Ellis handed your Secretary a check covering the final payment of the Section to the UEC Building Fund.

● President Chouinard met with AWS Sections at Rochester, Manchester (N. H.) and Worchester on October 16th, 17th and 19th. He and Vice-President Jackson presided at an all day AWS technical session in Detroit October 26th. During December President Chouinard and your Secretary will meet with AWS Sections in Dayton (12) and Milwaukee (15).

● As of mid-October fifty-nine AWS Sections had pledged their full quota to the UEC Building Fund. Less than $4000 in additional pledges is needed to meet the full AWS quota.

● On October 12th your Secretary was pleased to receive K. Aoyagi, managing director, T. Kinukawa, sales manager, and their associates S. Saito and M. Yamaka of Toyo Kanetsu Kogyo K. K., metal fabricating firm of Tokyo. This firm is now associated with the Pittsburgh-Des Moines Steel Co., and has established several records in constructing large storage and processing vessels for petroleum corporations in many parts of the world.

● Following a jet flight during a night shortened by the 5 hr change in time, Mrs. Plummer and your Secretary landed at Orly Airfield early on the morning of October 12th to celebrate both Columbus Day and Mrs. Plummer's birthday in Paris. Meetings of the Executive Council of the International Institute of Welding during the next few days provided an opportunity to confer with President Edstrom and his associate Hansen, Past-Presidents Goldschmidt, Guerera and Jaeger, Vice-presidents Frenay and Vedeler, Secretaries Parsloe and Leroy with their associates

Blosset and Boyd, and also with French Institute of Welding President Portevin and Vice-President Bastien. All but two of these outstanding leaders of welding activities in Europe, attended the Annual Assembly of the International Institute of Welding held in New York last April.

● All were interested in viewing the motion picture taken at the AWS Welding Exposition held in the Coliseum in New York. President Edstrom spoke during the opening ceremony and Mlle. Blosset with the assistance of President Chouinard cut the stainless steel chain, formally opening the exposition. Your Secretary presented a copy of the motion picture to Mlle. Blosset and the French Institute of Welding.

● On successive evenings Mrs. Plummer and your Secretary were entertained at (1) a delightful dinner with Mlle. Blosset, her mother and sister at their home facing the Bois de Boulogne, (2) a thrilling ride and dinner on a boat on the Seine viewing the illuminated buildings with Director Leroy of the French Institute of Welding (also Technical Secretary General of IIW), Mrs. Leroy and their two charming daughters, and (3) dinner and a very pleasant evening with Mr. and Mrs. L. Florin, an executive associated with René D. Wasserman.

● On October 17th the French Institute of Welding held a "reunion-cocktail" party, organized in honor of the visit of Mrs. Plummer and your Secretary, giving us an opportunity to greet the officers of the Institute and many members who attended the 1961 Annual Assembly of the IIW in New York, including Monsieur H. Granjon who presented the Adams Lecture at the AWS Annual Meeting.

● The following day was marked by a flight to Athens, Greece and the beginning of a vacation planned to include a cruise of the Greek Islands, a visit to Turkey, a short stay on the Italian Riviera and a return voyage on the Leonardo da Vinci.

From the Staff of the Welding Journal to All its Readers: A Very "Merry Christmas" and Best Wishes for 1962!!

TUFFALOY forged seam welder wheels provide the utmost in conductivity and long life. Photo by Taylor-Winfield Corporation.

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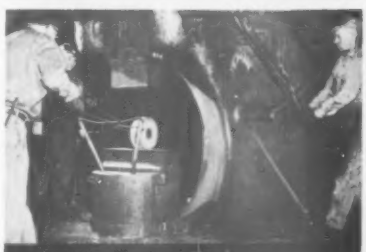

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Fourth Edition Welding Handbook

The Welding Handbook owes its success to the combined efforts of many people and to the generous cooperation of many companies. The last Section of the Fourth Edition is nearing completion and it is fitting that the AMERICAN WELDING SOCIETY expresses its appreciation and thanks to the hundreds of contributors who have worked so tirelessly to make the WELDING HANDBOOK the most authoritative work in its field.

It would be difficult, if not impossible, to calculate the thousands of hours spent in the preparation of this "bible of the welding industry." Each individual contributor has given far beyond what could have been reasonably expected of him. Work has been done at night, on vacation, in planes and in hotel rooms. Time has been snatched from technical sessions for committees to meet briefly and, despite pressure from other sources, deadlines have been met.

Contributors to the WELDING HANDBOOK are to be congratulated on having made publishing history. They have made it possible to publish a volume of approximately 550 pages each year—a feat considered impossible in publishing circles with a technical book prepared by committees. Section I was published in September 1957; Section V should be available for distribution next month.

To the following list of contributors we tender our sincere thanks

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Acker, H. G.
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"For Auld Lang Syne" . . .

The Editor and Editorial Staff of the WELDING HANDBOOK would like to take this opportunity of wishing you and all AWS members a Merry Christmas and a Bright and Prosperous New Year. We would also like to thank you for your wonderful help and forbearance. One of the greatest problems an Editor faces is meeting predetermined deadlines—and the need to harass his friends to complete assignments when they are already working at top pressure. The fact that you still remain friends is a great tribute to your understanding—please accept my most sincere thanks.

ARTHUR L. PHILLIPS
Editor, Welding Handbook

Authors . . .

please note!

January 15, 1962 is the deadline when application forms and abstracts must be postmarked in order to receive consideration for presentation at the 1962 National Fall Meeting to be held in Milwaukee, Wis., October 1-4.

The application form was included as a detachable insert in the October issue of the Welding Journal. Additional copies of the application may be obtained by writing to AWS headquarters, 345 East 47th Street, New York 17, New York.

SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Alabama

POWER SUPPLIES

Birmingham—The *Birmingham* Section held its first meeting of the 1961–62 season on October 10 at the Pick-Bankhead Hotel. Guest speaker was Warren Sykes, chief electrical engineer of Miller Electric Corp., Appleton, Wis. His subject was "Power Sources for Welding."

Mr. Sykes' talk covered a brief history of electric arc welding, an evaluation of machines to fit each new process developed and a résumé of the various types of welding power units and control methods.

Important points to evaluate when purchasing or applying welding equipment were also discussed. Physical improvements and modern operating features of welding machines were brought out.

The talk was very educational and was enjoyed by all.

WELDING POWER

Guest Speaker W. Sykes as he discussed "Power Sources for Welding" at the Birmingham Section October 10 meeting

California

MAJOR BRIDGE PROJECTS

Los Angeles—An enthusiastic turnout of 95 members and guests attended the first session of the *Los Angeles* Section on September 21 at the Rodger Young Auditorium. After a fine dinner, the meeting was called to order by Section Chairman Al Collins, who introduced the officers and committee chairmen.

The membership had the double privilege of having two guest speakers from the State of California division of highways. They were Leonard Hollister, special projects engineer, Bridge Department, and W. J. Jurkovich, project design engineer, Bridge Department. The program topic was "Impact of Welding on the Design of Major Bridge Projects in California."

For the past seven years Mr. Hollister has been special project engineer on the "Carquinez Straits Cantilever Bridge," the "Benecia-Martinez Truss Bridge" and the proposed new highway crossing between San Diego and Coronado and the "San Pedro-Terminal Island Bridge."

Mr. Jurkovich has for the past nine years been supervisor of a bridge design section on various types of structures. His speech covered the design and fabrication of the "San Pedro-Terminal Island Bridge" now under construction by Kaiser Steel Fabrication Division of Montebello, Calif.

Both speakers were presented with a pen and pencil set at the conclusion of the talks as a token of appreciation.

NEW SEASON GETS UNDER WAY

Guest Speaker W. J. Jurkovich at the September 21 meeting of the Los Angeles Section

Some of the many members and guests who were on hand on September 21 at the first meeting of the Los Angeles Section

MILITARY SPECIFICATIONS

Tustin—On September 28 the *Orange County* Section met at the Stax'n Snax Restaurant in Tustin for a dinner meeting. The guest speaker was John Larson, chief, Materials and Process Section, U. S. Army Ordnance District, Los Angeles.

His presentation of the "Rationalism of Military Welding Specifications" included examples of the environmental extremes that military equipment must be capable of withstanding and still be reliable. He also cited cases where the requirements of using welding procedures as required by specifications has substantially contributed to cost savings in some fabrication shops.

A very profitable question-and-answer session followed.

POWER SUPPLIES

San Diego—Forty-five members of the *San Diego* Section met on October 18 at the Midway Chuck Wagon to hear a talk on the subject "The Process and Power Source." The speaker was William Pierce of the Los Angeles branch of the Air Reduction Sales Co.

Through the use of various slides Mr. Pierce covered the field of gas tungsten-arc and metal-arc welding and their similarities and dissimilarities. By graphs he showed typical curves of electrical parameters of constant current, slope control, wave balancing constant arc voltage, controlled slope power sources and rising arc voltage power supplies. There was lively audience participation and Mr. Pierce brought together the salient characteristics of the various power sources and the reasons why they were developed.

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ALUMINUM BRAZING

Sunnyvale—The *Santa Clara Valley* Section's first dinner-meeting of the 1961–62 season was held on September 26 at Sabella's Restaurant in Sunnyvale and was presided over by the First Vice Chairman, Jerry Turner.

The meeting speaker was Robert B. Eckenstein, assistant supervisor of the Materials and Process Laboratory of the Air Research Manufacturing Co., Los Angeles. He discussed the subject "Aluminum Brazing" from a manufacturing engineering and production operation point of view.

One of the points stressed was the importance of the brazing flux used during the process. Some of the requirements for a satisfactory operating flux for use during brazing are: (1) it must be able to remove oxides and other detrimental surface materials, (2) it must flow easily and allow the filler metal to flow easily, (3) it must not attract the base material too readily and cause damage, and (4) it must be easily removed after the operation is completed. He feels that good fluxing conditions are the very essence of the brazing process.

Other points mentioned by Mr. Eckenstein were: importance of accuracy of heat control and exact temperature operation, adequate oven cleaning and maintenance and proper design for operation, necessity of time control in relation to temperature, the importance of joint design for strength and usability of end product and the importance of proper safety practices when performing the brazing operation.

SECTION MEETING CALENDAR

JANUARY 4

NORTHERN NEW YORK Section. Hot Shoppes, Route 9, Albany, N. Y. "Ultrasonic Welding," J. Byron Jones, Aeroprojects, Inc.

JANUARY 5

PHILADELPHIA Section. Panel Discussion—"Stainless Steel Electrodes: Titania, Lime Titania, and Lime Types."

JANUARY 8

BOSTON Section. "Fabrication of Primary Piping System of the Yankee Atomic Electric Plant," R. A. Loose, Westinghouse Electric Corp.

MILWAUKEE Section. Educational Program. First Session. Marquette University, Room 100. 7:00 to 9:00 P.M.

JANUARY 9

AUSTIN Division Houston Section. "Gas Cutting Structural Steels."

BIRMINGHAM Section. "Welding of Stainless Steels," Richard K. Lee, Alloy Rods Co.

DAYTON Section. "Flame Fluxing."

TULSA Section. Ware's Cafeteria. Dinner 7:00. Meeting 8:00 P.M. "Aircraft Alloy Welding."

WESTERN MASSACHUSETTS Section. Oaks Inn, Springfield, Mass. Cocktail Hour 6:00 P.M. Dinner 6:30. Meeting 7:45. Joint meeting with Connecticut Valley Chapter of American Society of Safety Engineers. "Storage and Handling of Cylinder Gases, Acetylene and Carbide," T. W. Kappler, Linde Co.

JANUARY 11

J.A.K. Section. Aurora, Ill. "Aluminum Welding."

KANSAS CITY Section. Wishbone Restaurant. National Secretary F. L. Plummer. "Some Aspects of Flame Cutting," A. F. Chouinard, National Cylinder Gas.

LONG ISLAND Section. Sunrise Village, Bellmore, L. I. "Recent Developments in the Welding of High Nickel Alloys," Kenneth M. Spicer, International Nickel Co.

MAHONING VALLEY Section. Joint meeting with Warren Chapter, ASM. Cafe 422, Warren, Ohio. 7:00 P.M. "Seconds for Survival and Big Bounce."

RICHMOND Section. "Bare Electrode Wires," Matt Waite, Arcos Corp.

SAGINAW VALLEY Section. High Life Inn, Saginaw, Mich. 7:00 P.M. "Automotive Welding," Tom Shear, Fisher Body.

ST. LOUIS Section. Ruggeri's Restaurant. "Complex Problems Arising in Welding of High Pressure Boilers," Roy Lorentz, Combustion Engineering, Inc.

JANUARY 12

COLUMBUS Section.

DETROIT Section. "Welding Metallurgy," Geo. E. Linnert, Armco Steel Corp.

NEBRASKA Section. National Secretary F. L. Plummer. "A New Consumable Electrode Spot Welding Process," A. F. Chouinard, National Cylinder Gas.

JANUARY 15

CORPUS CHRISTI Division, Houston Section.

MILWAUKEE Section. Educational Program. Second Session. Marquette University, Room 100. 7:00 to 9:00 P.M.

PHILADELPHIA Section. Engineers Club. "Weld and Heat Treatment of 15–25% Ni Steel," W. Fragetta, International Nickel Co.

JANUARY 16

HARTFORD Section. Dinner meeting. Villa Maria Restaurant. "Welding Metallurgy," Joseph Caprarola, Arcrods Corp.

NEW JERSEY Section. Essex House, Newark, N. J. Dinner 6:30. Meeting 8:00 P.M.

NORTHWESTERN PENNSYLVANIA Section. "Code Welding Procedures," R. H. Hoefler, Kaighin & Hughes.

OLEAN-BRADFORD Section. Castle Restaurant, Route 17, Olean, N. Y. Dinner 7:00 P.M. Meeting 8:00. "New Economies in Maintenance Welding with Modern Materials," J. P. Broderick, Eutectic Welding Alloys Corp.

JANUARY 17

FOX VALLEY Section. Appleton Elks Club, Appleton, Wis. Reception and dinner for President A. F. Chouinard.

HOUSTON Section. "Problems in Shop Welding," Harold Kretchmar, Phillips Petroleum Co.

PITTSBURGH Section. "The Uses of the Plasma Flame," James A. Browning, Thermal Dynamics Corp.

TOLEDO Section. Toledo Yacht Club. Dinner 6:30 P.M. Meeting 7:45. "Why Welds Fail," H. Thielsch, Grinnell Corp.

JANUARY 18

IOWA Section. "Large Weldment Fabrication," John H. Lang, Lukens Steel Co.

SABINE Section. "Problems in Shop Welding," Harold Kretchmar, Phillips Petroleum Co.

JANUARY 19

CHICAGO Section. Loop Meeting. Milner's Restaurant. Social 5:30 P.M. Dinner 6:15. Peoples Gas Auditorium. 7:45. "Plasma Arc Cutting and Surfacing," R. L. Hackman, Linde Co.

MICHIANA Section. "Hard Surfacing," Richard K. Lee, Alloy Rods Co.

JANUARY 22

MILWAUKEE Section. Educational Course. Third Session. Marquette University, Room 100. 7:00–9:00 P.M.

JANUARY 23

LOUISVILLE Section. Kentucky Hotel. 6:00 P.M. "Aluminum and Practical Aspects of Tig and Mig Welding of Aluminum," Howard E. Adkins, Kaiser Aluminum & Chemical Sales.

MARYLAND Section. Engineers Club, Baltimore. "Aluminum Welding," Ivan MacArthur, Olin Mathieson Chemical Corp.

JANUARY 24

WASHINGTON Section. Hotel Ebbitt, Washington, D. C. Dinner 6:30 P.M. Meeting 8:00. Washington Gas Light Auditorium. "Limitations of Processes," John Mikulak, Worthington Corp.

JANUARY 26

INDIANA Section. Buckley's, Cumberland, Ind. "Progress Through Arc Welding," F. Pilia, Linde Co.

JANUARY 29

MILWAUKEE Section. Educational Course. Plant Tour of A. O. Smith Corp.

JANUARY 30

CHICAGO Section. Calumet Meeting. Jockey Club, East Chicago. Social 5:30 P.M. Dinner 6:15. Meeting 7:45. "Shrinkage and Distortion," J. R. Stitt, R. C. Mahon Co.

JANUARY 31

CHICAGO Section. Two Days. Eighth Annual Midwest Welding Conference. Campus of Illinois Institute of Welding.

Editor's Note: Notices for March 1962 meetings must reach JOURNAL office prior to December 20th so that they may be published in the February Calendar. Give full information concerning time, place, topic and speaker for each meeting.

EMPLOYMENT OPPORTUNITY FOR ENGINEER

AWS is seeking an engineer to join Headquarters' Technical Staff as Assistant to the Technical Secretary

Here are the duties—

Working with AWS technical committees in gathering and correlating technical data; preparing minutes, reports and other records of committee activities; editing standards for publication as completed.

Disseminating technical information in answer to inquiries from industry.

Related duties as assigned.

Here are the qualifications—

Ability to work with technical men at all levels in a cooperative manner. This is necessary to deal successfully with committee personnel, AWS members and the general public.

A degree in engineering, any branch.

At least three years' experience in engineering work, preferably in welding or allied fields.

Here is an opportunity—

The man we are seeking has initiative and imagination and is interested in becoming familiar with welding in all its aspects and for every type of application. Salary will be commensurate with qualifications and experience.

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Aluminum material alloys which are presently being used for base material and their corresponding filler metals and fluxes were discussed to some degree. General shop production practices were covered. Lively discussion followed.

Colorado

ALUMINUM WELDING

Denver—The *Colorado* Section held its meeting on October 10 at the Americana Motor Hotel in Denver. For this meeting, an excellent motion picture film on the subject of "Aluminum Welding" was shown. The Reynolds Metals Co. has prepared this film as an educational and instructional film for anyone who is welding aluminum. It has been extensively shown and the members of the Colorado Section enjoyed it very much.

The coffee speaker was Dallas Cook, Director of Governmental Relations for the Denver Chamber of Commerce. His topic was "Practical Politic."

Connecticut

PLANT TOUR

Hartford—A comprehensive two mile tour of Pratt & Whitney Aircraft's main plant was held on September 20 by the *Hartford* Section. The tour showed all the various production welding operations involved in the manufacturing of a jet engine. This includes manual and automatic gas tungsten-arc and gas metal-arc welding, resistance, induction brazing, and covered electrode welding.

A visit to the Experimental Department showed three electron beam welding machines as well as other unique welding setups. The interesting and informative tour was concluded with a talk by William McGaw and Thomas Wheaton of Pratt & Whitney Aircraft's Industrial Power Department.

SECTION MEETING DATES • December 1961 through June 1962

Published to help AWS members plan trips . . . drop in on the nearest AWS Section the next time you are away from home.

Section	1961 Dec	1962 Jan	Feb	Mar	Apr	May	Jun
Albuquerque	14	11	8	8	12	10	14
Anthony Wayne	21	18	15	15	19	17	21
Arizona	..	..	..	..	..	..	..
Atlanta	..	..	..	..	..	..	..
Baton Rouge	21	18	15	15	19	17	21
Birmingham	12	9	13	13	10	8	12
Boston	11	8	12	12	9	14	11
Bridgeport	20	17	21	21	18	16	20
Carolina	25	22	26	26	23	28	25
Chattanooga	15	19	16	16	20	18	15
Chicago	21	18	15	15	19	17	21
	or	or	or	or	or	or	or
	22	19	16	16	20	18	22
Cincinnati	26	23	27	27	24	22	26
Cleveland	13	10	14	14	11	9	13
Colorado	12	9	13	13	10	8	12
Columbus	8	12	9	9	13	11	8
Dayton	12	9	13	13	10	8	12
Detroit	8	12	9	9	13	11	8
Eastern Illinois	27	24	28	28	25	23	27
Fox Valley	15	17	16	16	18	16	15
	or	or	or	or	or	or	or
	20	19	21	21	20	18	20
Greater Huntsville	28	25	22	22	26	24	28
Hartford	19	16	20	20	17	15	19
Hawaii	21	18	15	15	19	17	21
Holston Valley	19	16	20	20	17	15	19
Houston	20	17	21	21	18	16	20
Indiana	22	26	23	23	27	25	22
Iowa	21	18	15	15	19	17	21
Iowa-Illinois	14	11	8	8	12	10	14
J.A.K.	14	11	8	8	12	10	14
Kansas City	14	11	8	8	12	10	14
Lehigh Valley	4	1	5	5	2	7	4
Long Beach	15	19	16	16	20	18	15
Long Island	14	11	8	8	12	10	14
Los Angeles	21	18	15	15	19	17	21
Louisville	26	23	27	27	24	22	26
Madison-Beloit	21	18	15	15	19	17	21
Mahoning Valley	21	18	15	15	19	17	21
Maryland	26	23	27	27	24	22	26
Michiana	21	18	15	15	19	17	21
Milwaukee	15	19	16	16	20	18	15
Mobile	14	11	8	8	12	10	14
Nashville	14	11	8	8	12	10	14
Nebraska	8	12	9	9	13	11	8
New Hampshire	12	9	13	13	10	8	12

Section	1961 Dec	1962 Jan	Feb	Mar	Apr	May	Jun
New Jersey	19	16	20	20	17	15	19
New Orleans	19	16	20	20	17	15	19
New York	12	9	13	13	10	8	12
Niagara Frontier	28	25	22	22	26	24	28
N. Central Ohio	7	4	1	1	5	3	7
North Texas	14	11	8	8	12	10	14
N.E. Tenn.	12	9	13	13	10	8	12
Northern N. Y.	7	4	1	1	5	3	7
Northwest	11	8	12	12	9	14	11
N.W. Pa.	19	16	20	20	17	15	19
Oklahoma City	6	3	7	7	4	2	6
Olean-Bradford	19	16	20	20	17	15	19
Orange County	26	23	27	27	24	22	26
Pascagoula	13	10	14	14	11	9	13
Peoria	20	17	21	21	18	16	20
Philadelphia	18	15	19	19	16	21	18
Pittsburgh	20	17	21	21	18	16	20
Portland	12	9	13	13	10	8	12
Providence	20	17	21	21	18	16	20
Puget Sound	14	11	8	8	12	10	14
Richmond	14	11	8	8	12	10	14
Rochester	18	15	19	19	16	21	18
Sabine	21	18	15	15	19	17	21
Saginaw Valley	14	11	8	8	12	10	14
St. Louis	14	11	8	8	12	10	14
Salt Lake City	21	18	15	15	19	17	21
San Antonio	4	1	5	5	2	7	4
San Diego	20	17	21	21	18	16	20
San Francisco	25	22	26	26	23	28	25
Sangamon Valley	12	9	13	13	10	8	12
Santa Clara Valley	26	23	27	27	24	22	26
Shreveport	21	18	15	15	19	17	21
South Florida	20	17	21	21	18	16	20
S.W. Virginia	..	..	..	..	..	..	..
Stark Central	21	18	15	15	19	17	21
Susquehanna	6	3	7	7	4	2	6
Syracuse	13	10	14	14	11	9	13
Toledo	20	17	21	21	18	16	20
Tulsa	12	9	13	13	10	8	12
Wash., D. C.	27	24	28	28	25	23	27
W. Mass.	12	9	13	13	10	8	12
W. Mich.	25	22	26	26	23	28	25
Wichita	11	8	12	12	9	14	11
Worcester	11	8	12	12	9	14	11
York-Central Pa.	19	16	20	20	17	15	19

Florida

STEEL vs. CONCRETE

Hialeah—The *South Florida* Section held its first fall meeting on September 26 at the Citizens Federal Savings and Loan Association in Hialeah.

The meeting was opened by the newly elected chairman, Charles Hambuerger. Other elected officers for this year are: Bill Bushman, 1st Vice-Chairman; Charles Otto, 2nd Vice-Chairman; J. W. Gundrum, Treasurer, and Bill Floroplus, Secretary.

Program Chairman Harold Hose, introduced the guest speaker for the evening, Robert L. Crain, prominent structural engineer and AWS members, who gave a very interesting and informative talk on "Steel vs. Concrete" in high rise buildings.

Hawaii

WELDING DEVELOPMENTS

Honolulu—The first regular meeting of the *Hawaii* Section was held on September 29 at Elliott's Chuck Wagon in Honolulu, with an attendance of 29 members and 26 guests. The featured speaker for the evening was Clarence E. Jackson, who as vice-president of the AWS spoke on the activities of national headquarters and remarked that he was happy to learn that the Hawaii Section placed first, in membership gain, percentagewise.

Mr. Jackson then presented his subject "New Developments in Welding" which was accompanied with color slides. His presentation went back to the beginning of blacksmith forge welding and progressed to bare wire electrodes, shielded-arc, automatic short-arc and proceeded up to other latest developments. Of catching interest, was a slide he projected showing friction welding of a round bar accomplished by high speed pressure spinning with abrupt stop, in a lathe, taken by him on a recent trip to Russia. He also mentioned that welding development has spurted tremendously during the past ten years and was growing at a faster rate than the economy of the country. This is due, he said, to the step-up research undertaken by the welding industry. His lecture was very educational and of great interest to the members.

Mr. Jackson was on his return trip from Australia to New York. He is associate manager of Electric Welding Development for the Linde Co., Newark, N. J.

AT HOME 5000 MILES AWAY

National Vice-President C. E. Jackson is made to feel at home at the September 29 meeting of the Hawaii Section. Standing left to right are: J. T. Lee, Mr. Jackson, J. Horner, J. Stacy and D. Saunders

Illinois

LECTURE SERIES

Chicago—The *Chicago* Section has completed a very successful Educational Activities Lecture Series with nearly perfect attendance of 205 for the five evening sessions. Meetings were again held in the excellent facilities of the Chicago Bridge and Iron Co. "Dome" auditorium.

The series was opened by Bill Blackburn of International Harvester Co. with a dynamic presentation on shielded metal-arc welding. The second meeting was led by W. K. Johnson of J. T. Ryerson & Son Co., who presided over a panel of four experts on the subject of metal cutting. The third lecture on brazing was conducted by J. F. Rudy of Armour Research Foundation. The subject of submerged-arc welding was thoroughly covered in the last two meetings by the very capable team of L. J. Christenson of Chicago Bridge and Iron Co. and W. B. Root of Taylor Forge and Pipe Works.

The Chicago Section wishes to express its thanks to the speakers, the Educational Activities Committee members, Chicago Bridge and Iron Co. and all who participated in making this fourth annual lecture series an outstanding success.

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CHICAGO EDUCATIONAL LECTURE

Part of the very attentive audience of over 200 who attended the Chicago Section's Fourth Annual Educational Lecture Series

PLANT TOUR

Danville—The *Eastern Illinois* Section toured the Danville Plant of the Central Foundry Division, General Motors Corp., on September 27. Thirty-five members made the hour and a half tour of this twin foundry operation.

Dick Wilmott, plant personnel director, gave a brief description of the plant's operations from the international scope through the local facility operation prior to the tour of the Malleable Iron Foundry and the Gray Iron Foundry.

The Danville plant comprises a high production casting operation producing over 250 cast forms from ounces to about 250 lb. They stress a cast crankshaft developed in this plant and used extensively within the G. M. organization automotive plants as well as in other automotive works.

The meeting concluded with coffee and doughnuts in the plant cafeteria.

MILD STEEL WELDING

N. Aurora—The Joliet-Aurora-Kankakee (*JAK*) Section held its second meeting of the year at the Fox Valley Country Club on October 12. After dinner, a short business meeting was held at which it was reported that 39 people had signed up for the welding course to be given at the Elgin High School.

The speaker for the evening was Stephen A. Yasko of the Westinghouse Electric Corp., Buffalo, N. Y. His subject was "Inert Gas-Shielded Metal-Arc Welding of Mild Steel." Cost comparisons were made of all various processes, such as, covered electrode welding, submerged-arc and gas-shielded-arc welding. Characteristics of welding with different gases and power sources were also discussed. Slides of many automatic welding installations using inert gases were shown along with cost savings and production rates narrated by Mr. Yasko.

Indiana

PIPE WELDING

Lima—For the opening meeting of the *Anthony Wayne* Section, a Trailways bus was chartered for a plant tour of Standard Oil Co. in Lima, Ohio. The first part of the trip was through the maintenance and welding departments. Numerous special pipe, fittings and pipe-headers were being fit and welded. All joints were prepared for code welding and were fit in a precision manner. Their fitting was outstanding for this type of work. They were doing some build-up work for machining of various pieces. A number of pipe sections were lined with Monel and welded with nickel electrodes.

On the second part of the trip, Joseph Mack, Group Engineer explained the full operations of the plant to the group while the bus went over the plant roadways which covered 400 acres.

It was a very courteous and enjoyable trip for all.

TUBE FABRICATION

Elkhart—The *Michiana* Section began its 17th year of existence with a tour through the Bock Industries plant in Elkhart on September 19.

The main product of "Bock"

is the building of mobile house frames. A more recent product development is the making of square and rectangular tubes by framing and resistance welding. The machine which is used was specially designed by "Bock" and is unique in that many sizes of tubes can be formed using the same basic forming rollers.

Iowa

CO_2 WELDING

Des Moines—"The choice of a welding process is just a matter of common sense," Steven Yasko told members of the *Iowa* Section at their September 21 meeting held at the Hotel Kirkwood.

Mr. Yasko, representative of the welding division, Westinghouse Electric Corp., demonstrated the methods of choosing a welding process with particular emphasis on CO_2.

Mr. Yasko, who has been instrumental in the experimental development of automatic and semiautomatic welding, brought with his subject a wealth of wit and a down-to-earth approach that made his talk interesting as well as informative.

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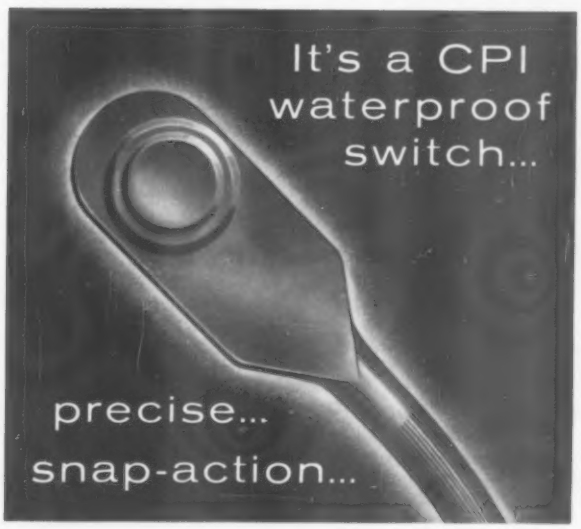

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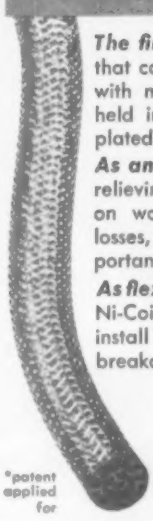

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HOSTS AND A SPEAKER

Dinner is under way before the Wichita Section meeting on October 9. Seated left to right are: W. Moore, W. Dent, Guest Speaker H. S. Davis and H. Nelson

POWER SOURCES

Moline—The *Iowa-Illinois* Section first fall dinner meeting was held in the Highland Bowl Sava Room, Thursday, September 14, with 40 members and guests present.

Warren L. Sykes, chief electrical engineer of the Miller Electric Manufacturing Co., Inc., Appleton, Wis., gave a most informative talk on the basic types of power sources, their shortcomings as well as their distinct advantages.

Kansas

MISSILES

Wichita—The *Wichita* Section held its monthly meeting at the Stockyards Hotel Dining Room on September 18.

Before the meeting there was a bus tour of Site No. 9 of the Titan II Missile Complex. The tour was conducted by O. B. Perkins, mechanical engineer, Corps of Engineers.

After the tour the members met at the Stockyards Hotel for a cocktail period before dinner. After dinner Mr. Perkins answered questions concerning the Site tour. Questions concerned the welding procedure on different applications at the silo. Mr. Perkins also discussed some of the cracking and weld failure problems he had encountered on this job.

Kentucky

PLASMA ARC TORCHES

Louisville—The *Louisville* Section held its regular meeting on September 26 at the Kentucky Hotel with 25 members present.

New officers for 1961–62 were introduced as follows: Chairman, David Carson, Sr.; Vice-Chairman, Eugene E. Schade; Secretary, Stanley A. Widman; and Treasurer, David Schelhorn.

Guest speaker was H. M. Gregorie, Chicago region engineer for the Electric Welding Department of the Linde Co., whose subject was "Plasmarc, New Welding Tool." He described the plasma arc and the two types of plasma arc torches, the transferred-arc and the nontransferred arc which differ physically in the electrical connections.

In the transferred-arc torch both the arc and the gas stream leave the nozzle. This type of torch is used mainly for cutting and for surfacing applications which require fusing the surfacing material to the base metal. With the nontransferred-arc torch the arc ends at the nozzle; only the hot discharged stream reaches the workpiece. Its greatest use is for plating. The plating material in the form of powder is heated to a plasma or molten state inside the torch and blasted onto the work piece.

A lively question period followed showing considerable interest in this relatively new tool for the welding industry.

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Also available on request are two new booklets: "A Full Line of Fine Welders" and "Questions and Answers on Rectifiers for Welding."

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Louisiana

ALUMINUM WELDING

Baton Rouge—"New Concepts in Aluminum Welding" was the subject of a program presented by Robert A. Hay, welding engineer of the engineering service department of Reynolds Metals Co., Richmond, Va. Mr. Hay used 35 mm slides for his talk and showed a film, "One Mile to Eldorado," which covered the progress made in Venezuela and the effects of American influence on the nation's economy as well as the tremendous work done on the fabrication of off-shore drilling towers by J. Ray McDermott of Morgan City, La.

The meeting of the *Baton Rouge* Section was held at the Sherwood Forest Country Club on September 21.

Massachusetts

MIT TOUR

Cambridge—The first regular meeting of the 1961–62 season of the *Boston* Section was held on October 9 and consisted of a visitation to the Welding Laboratory of the Massachusetts Institute of Technology. A catered dinner was served in the Metals Process Laboratory.

Technical speaker and host for the evening was Dr. Clyde M. Adams, Jr., associate professor of metallurgy at MIT. Dr. Adams outlined the different equipment on display in the laboratory and introduced staff members who operated the equipment and answered questions.

The equipment in the laboratory includes the usual conventional arc and resistance welding apparatus such as automatic and manual gas-shielded-arc welding equipment, submerged-arc welding, CO_2 welding and atomic hydrogen. This facility which is used for research and teaching at the graduate and undergraduate level also houses short-arc, capacitator discharge, ultrasonic and electron-beam welding equipment as well as apparatus for oxyacetylene metal and powder spraying and plasma-arc cutting.

The visitation enabled members of the section to become better acquainted with the research and teaching activities of the MIT Welding Laboratory as well as presenting an opportunity to examine a wide variety of welding processes not usually encountered

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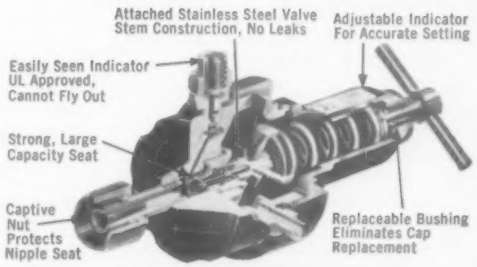
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CONGRATULATIONS TO A SPEAKER

A. Lindsey congratulates O. W. Blodgett (right) for his talk before the Detroit Section on October 13

in any one of the local industrial establishments.

GAS METAL-ARC WELDING

Springfield—David H. Brackett of the Linde Co., who is the New England Regional Engineer, gave a live demonstration of "New Developments in MIG Welding" to nearly 100 members and guests of the *Western Massachusetts* Section at a meeting held on October 10 at Springfield Trade High School. He explained that this is an inert-gas welding process using an automatic wire feeding device. Much interest was shown by all present and those who desired were permitted to use the equipment.

This very interesting meeting followed an excellent dinner at the Oaks Inn.

Michigan

WELDING DESIGN

Detroit—The *Detroit* Section, on the evening of October 13, was very fortunate to have as guest speaker, Omer W. Blodgett, design consultant, The Lincoln Electric Co., Cleveland, Ohio.

By means of blackboard and many slides, Mr. Blodgett outlined steps to be taken in design, fabrication and erection of steel which will lead to realizing the inherent advantages of welding. His discussion covered the importance of joint designs, continuity, shop welding, handling of miscellaneous connection plates, preparation of erection seats and holds, butt welding of beam to column connections, elimination of vertical welding, use of backing strips, use of stiffeners and cover plates and other code requirements.

He illustrated practices being used today in steel structures to give welding the best possible competitive position. His slides included the first all-welded building as well as the latest welded structures.

RESISTANCE WELDING INSTRUMENTATION

Saginaw—The *Saginaw Valley* Section held its October 12 meeting at the High Life Inn in Saginaw. District Director Ray Hoefler presented a brief talk on obtaining increased membership. I. Kehoe of the Westinghouse Corp. was technical speaker for the evening and spoke on "A Recommended Program for Resistance Welding Instrumentation." The meeting was attended by 55 members and guests.

This was a joint meeting with AIEE so that Mr. Kehoe's talk was very timely for both organizations. He described the instrumentation program which was initiated at Westinghouse plants to provide reasonable and reliable control of resistance welding jobs. A current transformer in the primary combined with a pointer-stop industry ammeter is considered best for single phase machines. For these phase machines, oscillograph equipment is used because generally up-slope, down-slope, postheat and weld heat cannot be accurately recorded by any other method. The program has been extremely successful at the various Westinghouse plants and was highly recommended for other industries where quality control is an important consideration. Following his presentation, Mr. Kehoe answered questions from the floor.

RESISTANCE WELDING

Grand Rapids—The first fall meeting of the *Western Michigan* Section was held on Monday evening, September 25, at Ducks Restaurant. There were 48 present for the usual fine meal and these were joined by 7 more for the coffee talk and technical session.

The coffee talk "Life in Jail" by Arnold Pigorsh, Kent County Sheriff, gave all the insights of life in a crowded jail.

The technical session was addressed by James F. Deffenbaugh, chief electrical engineer at Federal Machine and Welder Co., Warren, Ohio. His talk on "Resistance Welding of Aluminum Alloys" was

GREETING A GUEST

A. Lofsten (left) and L. Moses greet P. Oleno (center) who was guest speaker at the October meeting of the Long Island Section

accompanied by slides and was very interesting to all. Mr. Deffenbaugh called attention to several points and aids for the engineer and operator on the resistance welding of aluminum.

Missouri

SHORT ARC WELDING

Kansas City—Kenneth E. Richter, special project engineer, Linde Co., Development Laboratory, Newark, N. J., was the featured speaker at the September dinner meeting of the *Kansas City* Section. Mr. Richter presented to 57 members and guests a discussion of "Short Arc Welding." In addition to the discussion of current developments in the field of short arc welding an ultra-slow motion movie was shorn of the short arc welding of two plates.

The meeting was held Thursday, September 14, at the Wishbone Restaurant in Kansas City.

Nebraska

GLEN CANNON DAM

Omaha—A regular business meeting of the *Nebraska* Section was held on September 8 at the Birchwood Club. At this meeting the officers for the coming year were elected. At the close of the meeting, a thirty minute film, "Taming A New Frontier" on the engineering and building of the Glen Cannon Dam project was shown and enjoyed by all.

New Jersey

ANNUAL PICNIC

Union—On Saturday, September 16, the *New Jersey* Section held its annual picnic at the Old Cider

Mill in Union. The picnic was a success as evidenced by the 800 members and guests who attended.

Good food and sports events highlighted the affair, with plenty of door prizes. The biggest door prize "The Guess the Money Pot," was split by Ed Liable of the Jersey Welding Supply Co., and Joe Collander of the Buffalo Tank Co., each of whom guessed $349.67.

RESISTANCE WELDING

Newark—The first regular meeting of the season for the *New Jersey* Section was held on September 19 at the Essex House in Newark and was quite a success. Robert H. Foxall of the Federal Machine and Welder Co. was the speaker.

The 80 members and guests present had the privilege of listening to an interesting talk on "Basic Resistance Welding, Machines and Controls." Mr. Foxall conducted a lively question-and-answer period which followed the meeting.

New York

GAS-SHIELDED-ARC WELDING

Bellmore—The *Long Island* Section held its October meeting on Thursday, the 12th, at the Sunrise Village in Bellmore, L. I.

Due to urgent business, the scheduled speaker, W. J. Farrell of Sciaky Bros., Inc. was unable to attend. However, a very good talk was given by his assistant, Peter Oleno on "TIG and MIG Fusion Welding Developments" and was accompanied by slides.

NATURAL GAS CUTTING

New York—The October 10 meeting of the *New York* Section took place at Victor's Restaurant in New York City. Guest speaker of the evening was George R. Spies, who is associated with the Air Reduction Sales Co. His subject, "Natural Gas Cutting," represented a somewhat unique nature since this topic has not been too well publicized recently.

Mr. Spies began his talk by briefly reviewing the composition of natural gas. This led into certain historical data concerning the use of natural gas as a heating medium and then for metal cutting. The steps in the preparation of natural gas for industrial purposes were listed with the accent on the reduction of the natural pressure of 1000 psi down to the low pressure required for controlled dispensing. The mechanism of natural gas as compared to manufactured gases,

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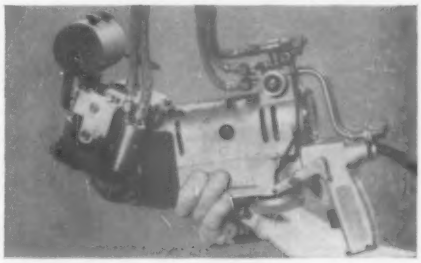

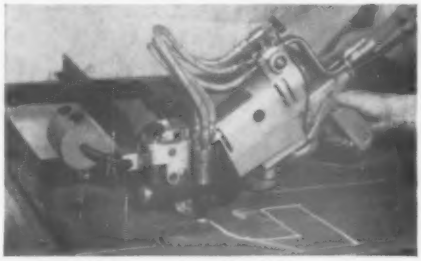

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ANNUAL PICNIC AND A MEETING

"Guess the Money" proved to be very popular at the New Jersey Section annual picnic in September. Among those participating were (left to right): J. Collander, A. Fleury, E. Liable and E. Bowden

Guest Speaker R. H. Foxall (right) is shown accepting gift from Program Chairman C. J. Sullivan at the New Jersey Section meeting on September 19

SPEAKER'S AWARD

G. R. Spies (left) is presented Speaker's Award by H. C. Phelps at New York Section October 10 meeting

such as acetylene and propane, was elaborated on. There are various advantages and disadvantages of each type from a cost viewpoint as well as heating capacity. Additionally, the hazards in handling certain of these gases were mentioned, with recommended maximum flow pressures.

Natural gas is used for cutting metals with or without preheat, depending upon the mass or cross-sectional area of the metal being cut. The geometry of the mixing chamber is important as well as the type and number of orifices. It was brought out that the location of the preheating orifices is not too critical when the skirted tip is used. It is, therefore, necessary to use proper equipment when cutting with natural gas. Tip designs vary according to the type of skirt and the number and size of the orifices.

The question-and-answer session following Mr. Spies talk indicated the interest aroused in the audience.

NUCLEAR RESEARCH CENTER

Buffalo—The September 28 meeting of the *Niagara Frontier* Section was held at Mann's 300 Club in Buffalo. The meeting was opened by Section Chairman James J. Russ who announced that a part of every meeting will be devoted to the discussion and answering of any type of questions related to the field of welding. The questions will be evaluated and answers given whenever possible at the next meeting.

The featured speaker was Dr. Ralph F. Lumb, Director of Western New York Nuclear Research Center, Inc. He gave a very informative lecture on the "Industrial Aspects of the Western New York Nuclear Research Center." Combined funds of industry, State of New York and the Federal Government made possible this very versatile research center which houses a million watt research reactor and two particle accelerators. The Center is located on the campus of the University of Buffalo. It is available to qualified research groups with or without the assistance of the Center's personnel.

Slides were shown of the Center's equipment and activities. The interior of a hot cell was shown with a machinist lathe being operated and sheet metal work being performed, using a hammer and chisel. All this was accomplished by operating remote control manipulators outside the radioactive shielded area. The Center also houses maintenance shops which have equipment ranging from welding to complicated electronic testing and repair equipment.

Due to an ionizing atmosphere in a nuclear reactor, corrosion is a very serious problem in metals. Because of the low operating temperatures, ranging from 100 to 170° F, aluminum was the metal selected for reactor tank and com-

SCALE MODELS FOR A SPEAKER

Guest speaker W. R. Rooney (center) with W. A. Owczarski (left) and L. E. Walker at the October 5 meeting of the Northern New York Section. The many models used by Mr. Rooney to illustrate his talk included the Vanguard satellite (shown left) and a globe of the world (to the right)

ponents which are further shielded with high density concrete.

Typical of services available is analytical equipment for measuring trace concentrations of many elements to parts per billion. One unique and interesting service that was rendered by the Center was to locate a leak in a radiant heating system which consisted of a network of circulating pipe buried under concrete. A very small amount of harmless radioactive solium was introduced in the system and traced with a detector, which revealed the exact area of the leak.

A highly spirited question-and-answer period followed the lecture. The group gave Dr. Lumb a standing round of applause for the splendid lecture he presented.

MAN'S NEW FRONTIER

Albany—William R. Rooney of the New York Telephone Co. spoke on the subject, "Space—Man's New Frontier," before approximately 40 members and guests at the October 5 dinner meeting of the *Northern New York* Section held at Hot Shoppes, Albany.

Mr. Rooney, with the aid of colored slides and scale models, outlined the progress in the race for space. He pointed out the importance of the products of commercial research to space efforts. For example, transistorized circuits powered by solar batteries provide much more dependable communcations than possible with conventional batteries. The Vanguard satellite launched in March 1958 was equipped with two communication systems. The battery unit has been inoperative for some time while the solar cell system is still in operation.

The speaker also discussed the potential of space satellites for commercial use and cited that last August the first message was bounced into space and back as part of Project Echo.

In conclusion, Mr. Rooney mentioned the various communication satellite programs which are being considered by the government and industry.

CORED-WIRE WELDING

Olean—The second meeting of the *Olean-Bradford* Section was held on October 17 at the Castle in Olean, N. Y. M. B. Prisuta, manager of research for National Cylinder Gas, gave a very good talk on Dual Shield welding. He discussed the characteristics and advantages of cored-wire applica-

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tions. Cost comparisons, geometric preparations of joints and qualities of this type of welding were also discussed. A thirty minute discussion period followed.

FLUX-CORED WELDING

Rochester—A. F. Chouinard, director of research and development for National Cylinder Gas Division, Chemetron Corp., Chicago, was the speaker at the October 16 dinner meeting of the *Rochester* Section held at the Liederkrantz Club. The subject of his talk was a "Progress Report on Flux-Cored CO_2 Process."

The fundamentals of the process were briefly described, including method of operation, wire compositions available and mechanical properties attained in the weld. Several extremely interesting case histories were presented to illustrate the general range of usefulness of the process. Mr. Chouinard closed with a frank appraisal of where the process could be utilized most effectively and also conducted a question-and-answer period.

CARBON DIOXIDE WELDING

Syracuse—The October meeting of the *Syracuse* Section was held on October 11 at LeMoyne Manor with 47 members and guests present for the program. Craig Sibley of the Air Reduction Laboratories in Union, N. J., was the speaker. Mr. Sibley's topic was the use and operating principles of carbon dioxide welding.

Ohio

NONDESTRUCTIVE TESTING

Cincinnati—The *Cincinnati* Section held its regular dinner meeting on September 19 at the Cincinnati Industrial Institute. The speaker was Warren J. McGonnagle of the Argonne National Laboratories, Chicago, Ill. His informative lecture was accompanied by slides that gave interesting examples of radiographic testing and sonic testing. Dr. McGonnagle feels that ultrasonics has the most promise in the future. He also mentioned that color film gives a much better radiographic picture. It was brought out that ultrasonics are very sensitive to cracks and a wide range of frequencies are usable. At the present stage, they are difficult to use on tubing. He mentioned that eddy currents is a new field for thin material inspection and will require more research, In closing, Dr. McGonnagle stated that he feels that increased cooperation between the welders, metallurgists, welding engineers and design engineers is necessary.

A question-and-answer period followed and several interesting discussions were held.

WELDED CASTINGS

Cleveland—The *Cleveland* Section held its opening technical meeting of the calendar year in quarters which were strange to newer members of the section but which held an air of familiarity to the old timers. The dinner meeting for October was held on the 11th at the Hotel Manger, the planned location of all future technical meetings for the coming year. Over 100 members were present when the meeting technical chairman, Omer Blodgett, introduced the guest speaker, John Bradner, Chairman of the Board of Lees-Bradner Co., Cleveland, Ohio. Mr. Bradner was capable of speaking with authority on his subject, "Why We Switched from Castings to Weldments."

The subject of his talk was the design conversion of a single spindle and a multiple spindle gear hobbing machine from a cast to a welded design. A period of approximately 12 years has seen a "tradition oriented" machine tool builder converted from a 100% casting user to a major weldment user, the speaker stated. Specifically discussing component parts, namely, splash guards, base, top housing, top ring, and motor plate of a typical hobbing machine, he pointed out that the welded design developed a 50% reduction in weight and cost while improving appearance. Although the present machines are of a composite design with the column and head stock still being cast, Mr. Bradner said that the great success with welded design will undoubtedly lead to the replacement of these members within the next ten years.

After the talk and an open question - and - answer session, the technical session was closed with a movie describing Russia's development and use of the Electroslag welding process.

HEAT EXCHANGERS

Columbus—Fifty members and guests of the *Columbus* Section enjoyed a chicken dinner at the Florentine Restaurant on Friday evening, September 15. After dinner the group toured the research and production facilities at Janitrol Aero Division of Midland-Ross Corp. where heat exchangers for aircraft and ground support equipment are made. The highlights of the tour were the metals-joining operations which included dip brazing of aluminum, arc welding of aluminum and stainless steel, and spot welding. Welding quality-control procedures were also demonstrated.

WELDING AND CUTTING

Warren—Harry Hooper, production sales manager, Air Reduction Co., New York, N. Y., gave a talk to some 40 members and guests of the *Mahoning Valley* Section on September 21 at the El Rio Restaurant. His subject was "Some Theoretical and Practical Aspects of Welding and Cutting." The lecture covered methods and techiques for welding and cutting. He described the basic equipment needed for welding and cutting, also including safety precautions necessary for correct operation. Mr. Hooper also explained the proper operation when cutting with two- and three-hose torches. A number of questions were asked by the members and were proof of a very successful meeting.

DISTORTION IN WELDING

Bucyrus—The speaker scheduled for the October 5 meeting of the *North Central Ohio* Section was, a few weeks prior to the meeting, involved in an automobile accident and was unable to fulfill his commitment for this evening's meeting. Walter Edwards, welding engineer for the Marion Power Shovel Co., was called upon at the last minute and came up with a thoroughly interesting and informative session on "Control of Distortion in Welding."

The subject was covered extremely well by Mr. Edwards and the local section was pleasantly surprised at the talent present right in their own group.

Mr. Edwards was the previous Section chairman and, during the evening, was presented with a Past Chairman's pin by the present Section Chairman, Al Tozer.

Also, during the evening a new membership chairman was appointed to replace Stan Wells of the Harnischfeger Corp. The new membership chairman is Terry Long of Metal & Thermit Corp.

Oklahoma

SHAPE CUTTING

Oklahoma City—National President A. F. Chouinard and National

VISITORS IN OKLAHOMA

National President A. F. Chouinard and National Secretary F. L. Plummer were guests of the Oklahoma City Section on October 2. Seated (left to right) are: R. E. McDermott, Mr. Chouinard and Mr. Plummer; standing are J. Sherman, J. Sampson, M. Barnes and P. Wedel

Secretary F. L. Plummer were guest speakers at the October 2nd dinner meeting of the *Oklahoma City* Section held at Cattleman's Cafe. Mr. Plummer made the opening address, during which he discussed AWS headquarters at the new United Engineering Center in New York City and headquarters personnel. Following Mr. Plummer's talk, a sound movie was shown describing the Welding Show which was held at the New York Coliseum in April. Of particular interest were the many exhibitors and the record breaking attendance.

Mr. Chouinard, as director of research and development for National Cylinder Gas Co., Chemetron Corp., discussed flame cutting with particular emphasis on the new shape-cutting machines and the photoelectric eye tracing equipment which has revolutionized the industry. Accompanying this talk were slides showing the photocell tracer, the new shape cutting machines available, and various applications. To end the meeting, Mr. Chouinard conducted a question-and-answer period on this equipment.

The local section was indeed fortunate in having both Mr. Plummer and Mr. Chouinard present at this meeting.

Pennsylvania

WELCOME OUTING

Jeffersonville—The *Philadelphia* Section launched its 1961–62 season on September 16 with the second annual "Welcome Outing" held at the Commercial Club in Jeffersonville and on the Schuylkill River. These outings are being received very favorably as evidenced by the large turnout of members and guests.

One very popular feature was the only stern wheeler on the Schuylkill. It is called the "Dynalloy Belle," and as the name implies, Allan Wood Steel Co.'s Dynalloy plate was used. It is of all-welded steel construction built by two employees of Allan Wood and runs regular scheduled cruises during the summer season.

The program of refreshments, snacks, dinner, games and boat rides was sufficient to entertain everybody.

PLANT TOUR

Essington—Lorin Poole's first Panel Meeting of the *Philadelphia* Section is to be considered a success judging from the attendance and interest shown.

THE DYNALLOY BELLE

Members and guests of the Philadelphia Section at the September 16 outing on the "Dynalloy Belle," only stern wheeler on the Schuylkill River

The first meeting on Friday, October 6, consisted of a tour of General Steel Industries, Essington, Pa., foundry.

Under the able guidance of Thomas Ditelfield, Jack Leonard, Bob Waite, Don Haines, Harold Levay and Elwood Tobias of General Steel, a group of approximately 65 members and guests saw a modern foundry at its best.

Of particular interest to the group was the latest laboratory equipment. The largest radiographic equipment in the Delaware Valley area and the extensive use of electric welding combined to make quality steel casting.

Open-hearth and electric furances are used here to make steels ranging from plain carbon, through manganese-moly, chrome-moly, HY-80 and nickel steels using the latest molding practices.

PRESSURE VESSELS

Barberton—The *Pittsburgh* Sec-

VISITORS FROM NATIONAL HEADQUARTERS

National President A. F. Chouinard discusses flux-cored CO_2 welding at Tulsa Section October 3 meeting

Visitors from National Headquarters pose with Tulsa Section officers and board members at October 3 meeting. Seated (left to right) are: J. C. Fairless, National Secretary F. L. Plummer, D. G. Ellis, National President A. F. Chouinard, W. E. McWilliams, J. Glenn and C. M. Huey; standing (left to right) are: L. Z. Johnson, R. Nichols, W. Dorsey, L. E. Coombs, R. C. Herod, R. H. Wainwright, J. H. Duerr, R. R. Vernow and J. C. Crabb

SEEN FROM ROSTROM

Guest Speaker D. L. Brugioni as he was being introduced at the Pittsburgh Section October 18 meeting

tion officially opened its 1961–62 year on September 22 with a plant tour of the Babcock and Wilcox Co., Barberton, Ohio. The group gathered at 7:00 A.M. in Pittsburgh and traveled by automobile to the plant.

The hosts escorted groups of five through the plant where they saw very heavy fabrication of high pressure steam boilers. This tour began at 10:30 A.M. and finished at 1:00 P.M.

The group were guests of B&W for lunch in the company dining room.

FABRICATION COST CONTROL

Pittsburgh—The *Pittsburgh* Section was privileged to hear D. L. Brugioni, metallurgical engineer for The Caterpillar Tractor Co., Peoria, Ill., speak on the "Control of Fabricating Costs in Manufacturing Operations." The meeting was held on October 18 at Mellon Institute following a get together dinner at Hotel Webster Hall.

Speaking in simplified but direct terms, Mr. Brugioni minced no words in pointing out some of the shortcomings of the welding industry (including his own) and constructively appraising some of the logical but most often overlooked procedures in the creation of manufacturing costs. He used an excellent series of slides to illustrate his presentation and succeeded in capturing the interest of all present.

The *Pittsburgh* Section highly recommends this presentation to all sections who have not been exposed to it.

STRUCTURAL WELDING

Shickshinny—The *Susquehanna Valley* Section held its first meeting of the season on October 4 at the Foothills Manor, Shickshinny, Pa. Sixty persons were in attendance, including members and guests, establishing the highest attendance on record by the Section for a technical meeting. Following an excellent dinner, the group was addressed by LaMotte Grover of the Air Reduction Co., New York City. His talk was entitled "Structural Welding, Design, Materials and Procedures."

Mr. Grover devoted a large part of his presentation to a description of some of the more recent structural steels, as covered by ASTM specifications, with particular emphasis on steel chemistry and its effects on weldability and the subsequent properties required in service. The beneficial effects of Mn and Si in improving notch toughness were noted and contrasted with the detrimental effect of increasing C content. Preheat recommendations for a variety of structural steels were quoted in terms of material thicknesses, preheat temperatures increasing as the ultimate tensile strengths of the steels increased.

Mention was made of several extremely heavy fabricated H sections, involving flange and web sections measuring 7 and 5 in. thick, respectively, which had been utilized recently in the construction of a multi-story Canadian building. These heavy sections and other specialized sections were not available in standard rolled sections. It was pointed out that welding afforded the designer an opportunity to specify "made to measure" sections when considered necessary without being entirely dependent upon standard rolled sections.

A brief description was given of orthotropic plate type steel bridge construction, made possible by the use of welding and permitting bridge spans up to as much as 856 ft compared with orthodox spans of approximately 250 ft.

Following the technical presentation, a Russian film depicting the basic principles of electroslag welding and showing many applications of the process in Russian industry. The film was very well received and is highly recommended for showing by other sections.

ELECTROSLAG WELDING

York—"Welding with the Electroslag Process" was the subject of a talk and a motion picture shown by Walter Wooding of the Arcos Corp. at the October 17 dinner

BEFORE DISCUSSION

Guest Speaker W. H. Wooding (left) and J. O. Cavanaugh (center) with J. Joyce open discussion at the York-Central open discussion at the York-Central Pennsylvania Section meeting on October 17

meeting of the *York-Central Pennsylvania* Section held at the Viking Club. Slides were used to describe the process and give details on physicals and chemistry of weld deposits. Some of the slides and the motion picture showed actual applications in the United States, Russia and Europe.

The motion picture was first shown in this country at the 42nd Annual Meeting by Prof. B. E. Paton of the USSR in connection with presentation of his paper on the subject. It quickly explains the principles of electroslag welding in its different forms. Scenes include the Paton Institute of Welding in Kiev and numerous interior views of heavy industrial plants in Russia.

Rhode Island

CLAD STEELS

Providence—The *Providence* Section held their monthly dinner meeting at Johnson's Hummocks on Wednesday, October 18.

Richard S. Rote, head of the Welding Laboratory of Lukens Steel Co., gave a talk entitled "Welding and Fabrication of Clad Steels." His interesting lecture was accompanied by slides and he explained the uses and methods of cutting and fabricating clad steel as well as the resulting savings in material cost.

Tennessee

WELDED PRODUCTS MONTH

Nashville—The week of April 24, 1961, was a busy one for members of the *Nashville* Section. During that week Governor Buford Ellington and the Mayor of Nash-

PROCLAMATIONS FROM TENNESSEE

Nashville Section receives proclamation declaring April in 1961 as Welded Products Month from the Governor of Tennessee. Left to right are: J. Price, G. J. Merrick, W. P. Regen, W. M. Belew and Governor Buford Ellington

The City of Nashville also proclaimed April 1961 as Welded Products Month. Standing left to right are: G. J. Merrick, J. Price, D. Hart, W. P. Regen, Mayor Ben West of Nashville, W. M. Belew, R. Aschinger and L. A. Tanksley

ville, Ben West, officially declared April to be Welded Products Month.

Highlights of these events were culminated by several members of the Section visiting both the Governor's office and the Mayor's office, where they were received and entertained by the public officials.

Local newspapers, radio stations and television stations carried feature articles covering the events, as well as paying tribute to local concerns engaged in various types of welding and fabricating. Middle Tennessee is fortunate in having a wide variety of this type work being done. Local plants range from those manufacturing miniature electronic capacitors and other electronic parts for civilian and defense applications—up to complete bridges, boats, dredges and even missile launching and testing equipment.

Some 30 area manufacturers of welded fabricated products cooperated with the Section by featuring displays of their many products, calling attention to the many advantages to be found in buying welded products.

The week's events were considered very successful by those participating and they are looking forward to an even larger program and activity next year.

In addition to the above, the Section was awarded the Henry Neitzel Award for the previous year's activities, during which they attained the greatest net percentage increase in section membership.

PIPE LINE FOR SULFUR

J. M. Shilstone discusses molten-sulfur pipe at Northeast Tennessee Section meeting on September 12

MOLTEN SULFUR PIPE LINE

Oak Ridge—The *Northeast Tennessee* Section opened its technical meeting year with a dinner meeting at the Holiday Inn in Oak Ridge on Tuesday, September 12. Forty-four members thoroughly enjoyed a most interesting and informative talk by J. M. Shilstone, national director of District No. 4 and partner, Shilstone Testing Laboratory, Baton Rouge, La.

Mr. Shilstone spoke on "The Design, Welding Procedure and Fabrication of Concentric Molten-Sulfur Pipe Line." The presentation covered all of the fabrication problems and their solution in constructing a 35,000 ft long, hot double-jacketed pipe line installed in the Gulf of Mexico for transporting molten sulfur at 300° F from a salt dome over 1800 ft deep into the Gulf to a processing plant seven miles on shore. His talk was supplemented with color movies and slides of the project.

The talk had a timely interest as the offshore mining platforms described had just withstood the full force of Hurricane Carla's 150 mph winds. The 1500 ft long rigid steel structure of 55 ft clearance over the water was described to be designed to withstand the violence of tropical hurricane winds up to 115 mph and 43 ft breaking waves.

Texas

PRESSURE VESSELS

Houston—One hundred and twenty members and guests of the *Houston* Section met at the Houston Engineering & Scientific Society on September 20 for the kick-off meeting of the new year. Season spirit for the coming months was quickly aroused by the predinner showing of an excellent football film "Southwest Conference Highlights of 1960."

The Section was fortunate to have as guest speaker, P. O. Leach of Combustion Engineering, Inc., Chattanooga, Tenn., whose topic for the evening was "Welding of Pressure Vessels." Mr. Leach's talk was profusely illustrated with slides showing the wide range of heavy wall-fired and unfired ASME vessels as well as nuclear reactors and components fabricated at Chattanooga. Mr. Leach also described a method of weld cladding which results in very little penetration of the base metal and consequent minimum weld dilution.

EDUCATIONAL ACTIVITIES

The Educational Committee of the *Houston* Section composed of Stanley Scales, chairman, James Walker and James Grove has developed plans for the Section's spring education program.

The program will include an eight session course on "Metals and Their Weldability" using Section Four of the WELDING HANDBOOK as a text. Certificates will be awarded all students attending.

A registration party on January 30, 1962, will precede classes starting on February 6.

DESPITE THE DEVASTATION CAUSED BY CARLA . . .

Even though Hurricane Carla had slammed into Texas a short while previously, more than 120 members and guests gathered for the "Kick-Off" meeting of the Houston Section on September 20

Pressure vessel welding was the technical subject for the first meeting of the Houston Section. Standing left to right are: V. Thompson, H. Olsen, Guest Speaker P. O. Leach and L. Manchester

Washington

VACUUM SYSTEMS

Seattle—"Fabrication of Hard Vacuum Systems" was the subject of a talk given by Ed Cornwall of the Boeing Airplane Co., Seattle, on September 14 at the *Puget Sound* Section meeting held at the Engineers Club.

Mr. Cornwall's talk covered general design, welding fabrication and test procedures. Hard vacuum refers to vessels in which atmospheric pressures are less than 1/1,000,000 atmospheric pressure. Use of these vessels is planned for welding of titanium and other "exotic" metals. Numerous methods of weld leakage covered of which "Helium Sniffer" most used.

Coffee speaker was Lawrence Benedict of Century 21 World's Fair which is to be held in Seattle in 1962.

Wisconsin

SAFETY

Janesville—The *Madison-Beloit* Section met on September 21 at La Pads Supper Club in Janesville for dinner and meeting. Featured speaker was K. F. McKenzie, owner of McKenzie Welding Equipment Repair, St. Paul, Minn. The title of his talk was "Safety and Savings Through Maintenance."

Mr. McKenzie's presentation could have been aptly titled, "From the Tank to the Flame," and was of great interest to the entire group. Only a man dedicated to safety could give this talk so well as to hold all present practically spellbound for the duration.

WELDING POSITIONERS

Milwaukee — The *Milwaukee* Section held its regular monthly meeting on Friday, September 22. The preliminary of the meeting included the awarding of two welding books, which were followed by narrated movies of the successful Green Bay Packers Western Conference champs, "Highlights of 1950." Speaker at the technical meeting was Anthony K. Pandjiris of Pandjiris Weldment Co., St. Louis, Mo. As a leading designer and a producer of welding positioners and welding processes, Mr. Pandjiris presented welding methods for steels from 0.008 to over 1 in. thick.

One of the latest welding processes described was the "Electro-Mold" process wherein vertical positioning and water-cooled copper sidewall dams were used in conjunction with a submerged arc.

He cautioned about expecting immediate automatic operation of a new setup and explained that practically never can you get final smooth, money-saving, automatic operation before knocking out the "bugs."

Among the many slides shown was included an overhead boom to which the welding head and apparatus are attached, to be lifted away somewhat similar to a crane and then lowered into place at another weldment. Mr. Pandjiris felt this principle would get more use in the future.

Attendance for this meeting, a third re-engagement for the speaker over the years, was 93 for dinner and 102 for the technical talk. This was good attendance despite rain all through the day and a record rainfall of 2.25 in. over 50 minutes at Milwaukee airport weather station.

STRESSING A POINT

Guest Speaker K. F. McKenzie stresses a point with the help of a cleverly drawn cartoon at the Madison-Beloit Section meeting on September 21

EDUCATIONAL SERIES

Milwaukee — The *Milwaukee* Section has formulated an interesting series of talks and speakers for their monthly meetings, as well as an educational lecture series to be held on January 8, 15, 22 and 29, 1962. This series will stress the fabrication of low-alloy, high-strength steels.

CONGRATULATIONS

Guest Speaker A. K. Pandjiris (left) receives the congratulations of L. E. Bluhm for an excellent talk at the September 22 meeting of the Milwaukee Section

New Members

EFFECTIVE OCTOBER 1, 1961

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	203
Members	6,577
Associate Members	5,728
Students	363
Honorary Members	11
Life Members	31
Total	12,913

ALBUQUERQUE
Tollett, Harley (B)

ARIZONA
Francisco, Warren B. (B)

BOSTON
Whouley, Richard J. (B)

BRIDGEPORT
Dunbar, George E. (B)

CAROLINA
Szostak, Boleslaw (B)

CHICAGO
DeeFloyd, Ernest (B)
Dempsey, Chas. E. (B)
Falkenburg, Clarence E. (B)
Harders, Harry (C)
Morrison, Charles E. (B)
Novell, John (B)
Stahler, John R. (B)

CINCINNATI
Huschke, Ernst G., Jr. (B)

CLEVELAND
Baylie, Neil (C)

COLUMBUS
Houck, Frederick D. (C)

DAYTON
Boyce, Wilfred A. (C)

DETROIT
Darlington, Robert G. (B)
Halberda, Donald M. (D)

FOX VALLEY
Vander Wielen, Raymond (C)

HARTFORD
Argo, Edward T. (C)

HAWAII
McAfee, Donald L. (B)
Richey, Robert B. (C)
Wilson, Edward T. (C)

HOUSTON
King, Frederick (C)
Miller, Viggo (B)
Nettles, Joseph S. (C)

INDIANA
Sparks, T. I. (B)

IOWA
Mishmash, Harold (B)

J. A. K.
Bell, Robert A. (C)

KANSAS CITY
Kenyon, C. P. (B)
Zook, Raymond D. (B)

LEHIGH VALLEY
Tall, Lambert (B)

LONG BEACH
Cochran, John B., Jr. (B)
Schmidt, Kenneth W. (B)

LONG ISLAND
Pelkowski, Francis (C)

MAHONING VALLEY
Hames, Richard (C)

MARYLAND
Dossey, Lawrence (B)
Goode, Robert E. (C)
Kidwell, Richard F., Sr. (B)

MILWAUKEE
Porter, Delbert D. (C)
Wiggins, Roger J. (C)

MOBILE
Nicolson, Norman A. (C)

NEBRASKA
Popham, Wayne R. (C)

NEW JERSEY
Bielenberg, James G. (B)
Boland, Richard W. (B)
Cornine, Irving A. (B)
Ferraioli, Frank (C)
Thomas, Fred (B)

NIAGARA FRONTIER
Guggemos, Clarence J. (C)

NORTHWEST
Christensen, C. B. (B)

OLEAN-BRADFORD
Ames, James (D)
McGee, Fred (D)

PASCAGOULA
Greer, Everett (C)
Saucier, Hugh W. (C)

PEORIA
Ague, Lloyd P. (C)

PHILADELPHIA
Laroe, Thomas A. (B)
MacGregor, Raymond E. (B)
Roberts, Ben W. (C)

PITTSBURGH
Black, Herbert L. (C)
Godwin, Ronald (C)
King, Jack W. (B)
McDermott, John F. (C)

PROVIDENCE
Walsh, Richard P. (B)

PUGET SOUND
Correy, Thomas B. (B)
Fisk, Ivan R. (C)
Herdt, Alan R. (B)

RICHMOND
Harris, Robert L. (B)
McAdams, Elmer I. (B)
Simmons, Harry F. (B)

ROCHESTER
Smith, Howard A. (B)

SABINE
Koval, A. S. (B)

SAN DIEGO
Morrison, W. O. (B)

SOUTHWESTERN VA.
Drabo, Michael J. (D)

STARK CENTRAL
Woolf, Frank H. (C)

TULSA
Brown, Jim C. (B)
Brown, Lee (B)
Clark, Bill (B)
Clemmons, Jess Al. (B)
King, H. Clay (B)
Luce, Quell (B)

WASHINGTON, D. C.
Camp, Robert A. (B)

WORCESTER
Pulsifer, Irving E., Jr. (B)

MEMBERS NOT IN SECTIONS
Almqvist, Goran Folke (B)
Bastien, Paul Gaston (B)
Constant, M. A. (B)
Cossmann, Jack R. (B)
Doneux, Georges (B)
Goeau, Alain, L. (B)
Jain, D. P. (B)
McGibbon, L. O. (C)
Moss, V. J. (B)
Reisser, S. Melya (B)
Tsui, Leung Butt (B)

RECLASSIFICATION DURING OCTOBER 1961

CINCINNATI
Davis, B. J. (C to B)

CLEVELAND
Heyman, Gustave C. (C to B)

COLUMBUS
Riegle, Robert L. (C to B)

HOLSTON VALLEY
Deakins, John H. (C to B)
Todd, James M. (C to B)

J. A. K.
Lee, Ken (C to B)

LONG BEACH
Garfield, Gerald (C to B)

NORTH TEXAS
Wells, Burton A. (C to B)

PITTSBURGH
Hoffman, William F. (C to B)
Thom, Willlam F. (C to B)

SAN FRANCISCO
D'Annessa, Anthony T. (D to C)
Haley, William M. E. (D to C)

TOLEDO
Brenner, Edward L. (C to B)
Homrighaus, A. H., Jr. (C to B)

TULSA
Ellis, Duane G. (C to B)

WESTERN MICHIGAN
Pifer, John William (C to B)

NEWS of the industry

AWS Members Participate in '61 Space Show

An estimated 15,000 space scientists and engineers attended the American Rocket Society's 16th annual "Space Flight Report to the Nation" held at the Coliseum in New York City, Oct. 9–15.

Among the more than 200 aerospace industry exhibitors, including the Dept. of Defense and NASA, 22 AWS member companies participated in the exposition: Airco, Alcoa, Bell Telephone Laboratories, Boeing, Cutler-Hammer, General Electric, General Motors, Linde Co., Lukens Steel, Marquardt Corp., Northrop, North American Aviation, Ryan Aeronautical, Tempil° and Westinghouse.

A series of displays and exhibits were devoted to new developments in the space industry and, in instances, welding techniques used in the fabrication of aerospace craft and component parts.

For the public, the first three floors were devoted to present and prototype space craft, space capsules, boosters, missiles and U.S. satellites depicted in orbit around the globe. The main attraction was Project Mercury, while other displays of extreme interest depicted simulated trajectories to the moon, designs of a moon base and communication satellites soon to be orbited.

This comprehensive exposition, as reported by the *New York Times*, "... offered the layman the closest view likely to be available for some time this side of the installations at Cape Canaveral."

ASTM Changes Name

The name of the American Society for Testing Materials was officially changed to the American Society for Testing *"AND"* Materials with the signing of a court decree amending the Society's Charter originally granted in 1902 by the Commonwealth of Pennsylvania.

In announcing the change, ASTM President M. N. Clair said, "The inclusion of the word 'and' in the Society's name places added emphasis on the Society's research work in seeking knowledge of the nature of materials."

Scholarship Awarded for Welding Engineering

York Engineering — Chicago Welding Sales 1961–62 scholarship award for Welding Engineering has been made to an Ohio State University, third year welding engineering student, Patrick R. Scott of Kettering, Ohio.

The following exerpt of his letter was sufficient reward for those interested in the future of welding to justify the support of welding education activities, stated Irving Silver, president of the donor companies: "I had no idea as to what type of engineering I wanted. Welding Engineering seemed to be the

Patrick R. Scott

COMING EVENTS

A Calendar of Welding Activity

AWS

Apr. 9–13, 1962. 43rd Annual Meeting and Exposition, Cleveland, Ohio

AIEE

Jan. 29–Feb. 2. Winter General Meeting and Engineering Exposition. New York Coliseum.

AIME

Dec. 6–8. 19th Annual Electric Furnace Conference. Penn-Sheraton Hotel, Pittsburgh, Pa.

Jan. 17, 1962. Fourth Annual Mechanical Working Committee Conference. Pick-Congress Hotel, Chicago, Ill.

ASME

Jan. 24–26. Second Symposium on Thermophysical Properties. Princeton University, Princeton, N. J.

ASTM

Feb. 5–9. Committee Week. Statler Hilton Hotel, Dallas, Tex.

* * * *

Jan. 22–25. 1962 Plant Engineering & Maintenance Show. Convention Hall, Philadelphia, Pa.

most versatile of all the engineering curricula offered, thus it became my choice. At the time, my thoughts were to stay in welding until I decided what to do, then to switch to another college. Now, after becoming more acquainted with the field, I tend to feel that my somewhat haphazard choice was one of the wisest I have ever made. To me, it seems that a welding engineer can do most anything. This is my motivation now—to be able to do most anything."

International Prize Contest

The Permanent International Commission on Acetylene, Gas Welding and Related Industries has established a prize contest for papers on two subjects: (1) tests, studies or research on the stability of the flame of the oxyacetylene torch in various applications; theoretical studies, or experimental research, or methods of operation, or design features are acceptable; (2) studies on improving oxyacetylene cutting in two respects: (*a*) cutting large thicknesses, (*b*) increasing the cutting speed.

The paper must not have been published prior to Apr. 1, 1962. Five typewritten copies of the paper in French or English on 8 x 12 in. paper with a max of 20 pages must be sent to the General Secretariat of the Permanent International Acetylene Commission, 32 Boulevard de la Chapelle, Paris 18, France, not later than Mar. 31, 1963. The minimum prize is 1000 Swiss francs ($230) and a total of 12,000 Swiss francs will be awarded.

Molybdenum Coated With Nickel Alloy

New York Testing Laboratories, Inc., reportedly has successfully coated molybdenum with an alloy bonded nickel alloy coating. This coating will protect molybdenum at elevated temperatures where it would ordinarily be subjected to severe oxidation corrosion.

Since molybdenum has a relatively high strength at elevated temperature, this process will increase its life preventing accelerated oxidation.

The applications for this material combination are apparent for high performance aircraft and missiles where temperature effects are important on structural parts. Since molybdenum has a high strength to weight ratio at elevated temperature but poor oxidation resistance, the protective coating is a very important step in solving this problem.

The alloy bonding qualities of the coating process allow this material to be worked after coating without exfoliating.

Welding Symposium Held in London

The 1961 autumn meeting of the Institute of Welding in cooperation with The Royal Institution of Naval Architects, The Institute of Marine Engineers, The Institution of Engineers and Shipbuilders in Scotland and the North East Coast Institution of Engineers and Shipbuilders presented a "Joint Symposium on Welding in Shipbuilding," October 30–November 3 in London, England. The technical sessions included papers on design, materials, yards and construction, welding and cutting and quality control.

Lincoln Awards to 53 Engineering Students

The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio, recently granted awards to 53 engineering undergraduate students for their outstanding entries in the Foundation's annual "Engineering Undergraduate Award Program for Arc Welded Designs of Machines or Structures" established to stimulate interest, scientific study and research in the practical design and use of arc welded steel. The awardees represented 29 colleges from all parts of the country.

In the Machine Division, R. W. Gerstenberger, an electrical engineering student at the University of Miami (Florida), was granted the $1500 First Award for a "Design Study of a Welded Engine Block," using steel's premium mechanical and physical properties and the flexibility of arc welded as a fabrication technique to reduce weight and machining operations and control production costs.

J. M. O'Neal, an architectural engineering student at Rensselaer Polytechnic Institute, led the Structural Division with his design study of "An All Welded, Prefabricated Space Frame," a design presentation demonstrating that a space frame system is highly flexible and readily adaptable to varied construction conditions. In addition, the basic component parts lend themselves to the economies of mass production prefabrication. His paper was granted the $1500 First Award.

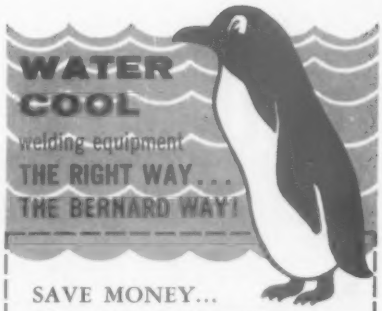
German Welding Fair

The West German Welding Society held its Welding Fair in Essen, during September 1961.

The main line of development by commercial firms appeared to be greater economy through mechanization. The CO_2 welding process

VENEZUELANS VISIT HOBART BROTHERS

First hand familiarity with the current scope of Hobart Brothers Co. factory operations and export personnel was the goal attained by Mr. and Mrs. W. R. Hinkle, during their recent visit to Troy, Ohio. Mr. Hinkle, third from right, is vice-president of C. A. Gases Industriales de Venezuela, Hobart distributor in Venezuela. Others are (left to right) R. L. Sherwood [AWS], W. H. Hobart, Jr., [AWS], and J. C. Brownewell



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what you want in
electrodes

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WE BELIEVE WE DO, TOO!

HARNISCHFEGER
Milwaukee 46, Wisconsin

P&H
WELDING PRODUCTS DIVISION

was the fastest growing of the rapidly developing gas-shielded processes. Controls were available for projection, seam and spot welding entire assemblies. Recording equipment for welding data had advanced. In the resistance welding field, multipurpose machines, such as combined projection and spot welders were available. A high-frequency automatic welder for spiral pipe was available. Fully mechanized welding in all position had arrived. Greater emphasis was being placed on electroslag welding, especially for the thinner cross sections.

Several welding fabricators exhibited interesting applications of welding. Salzgitter Co. showed spiral welded pipe and welded marine diesel frames. The GHH firm exhibited electromagnets for electron accelerators of the Electron-Synchrotron firm in Hamburg.

Alloy Rods Appoints Distributors

Alloy Rods Co. recently announced the appointment of two new distributors for their complete line of alloy welding electrodes, rods and wires: Peterkin Welding Supply Co. of Newburgh, N. Y., and General Welding Supply Corp. of Westbury, L. I., N. Y.

American Brazing Builds

American Brazing Alloys Corp., Pelham, N. Y., is now completing a 12,000 sq ft plant. The addition will be used for flux coating and wire drawing, spooling, straightening and cutting. The firm produces the following alloys: low fuming bronze, nickel silver, phosphor copper silver alloys, silver solders and aluminum welding wire.

North Carolina Welding Clinic

More than 200 people attended a welding clinic held recently at Andy-Oxy-Co., Hendersonville, N. C. William Anderson, head of the company, said that metallurgists, engineers, superintendents, foremen, purchasing agents and others from all parts of western North Carolina attended.

There were demonstrations of NCG welding equipment and a complete line of personal protection equipment was displayed as well as medical equipment for use in emergencies in industrial plants and hospitals.

Magnesium in Focus

The theme of the recent annual convention of the Magnesium Assn's., "Magnesium in Focus," was held October 16–18 in New York City. Through presentation of technical papers and discussions, the latest methods, techniques, applications and other progress in magnesium were presented and supported by one of the finest exhibits of its kind, designated as "101 Commercial Uses of Magnesium."

Among speakers scheduled was W. G. Groth III of the George C. Marshall Space Flight Center at Huntsville, Ala., on "When Specific Customer Standards of Specifications Are Necessary: Why General Specifications Will Not Serve."

Greenewalt Awarded John Fritz Medal

C. H. Greenewalt, president of E. I. du Pont de Nemours & Co., will be the 1962 recipient of the John Fritz Medal, the highest honor of the engineering profession, the John Fritz Medal Board of Award recently announced by the United Engineering Trustees, Inc., of New York, N. Y.

Established in 1902, as a memorial to the great engineer and steel maker whose name it bears, the medal has been presented to some of the world's most distinguished engineers and scientists, including Westinghouse, Alexander Graham Bell, Edison, General Goethals, Orville Wright, Marconi, Sperry, Hoover, Pupin and Kettering.

Mr. Greenewalt was cited "For outstanding contributions . . . through leadership in research, in the translation of research achievements by way of sound engineering into useful products," and through his "able championship of the American free enterprise system both in the spoken and written word."

Home Study Course for Welding Operators

For over 12 years the Canadian Welding Bureau, a Division of the Canadian Standards Association of Toronto, Ont., has provided a home study course for welding supervisors.

Now for the first time, according to the bureau, it is offering a similar "do-it-yourself" course for welding operators, a home study course covering those basic theories and fundamentals involved in his art.

The course is open to all. It is sent complete, simply written, basic and within the capacity of those who want the satisfaction of accomplishment and of knowing their business. Diplomas are granted.

Details may be obtained from the Canadian Welding Bureau at 1393 Young St., Toronto 7, Ont., Canada.

you do the job better
with Airco quality equipment . . . this is because Airco designs, engineers and produces everything you need to do any welding or cutting job properly, no matter what it is. Airco precision components *work together better* . . . are *matched* to the job.

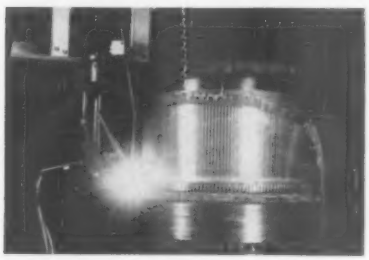
AIRCO®
AIR REDUCTION
More than 700 Authorized Airco Distributors Coast to Coast

For specifics see the Airco ad on the back cover of this issue.

Hot Spot for Railroads

The announcement of a new General Electric gas tungsten-arc welding process to increase the reliability of rebuilt traction motors for heavy diesel electric locomotives that would help railroads realize more miles per maintenance dollar was made recently by Lee H. Hill, Jr., sales manager.

Used for making the connection between the armature coil lead and commutator riser, this method results in an all-copper joint, providing better protection against high temperature damage and making armature coil repair and rewinding easier. Using tungsten for the electrode and an inert gas to shield the molten weld puddle from atmospheric contamination, soldering and its associated difficulties are eliminated, since the coil lead and riser are fused together. The result is a weld with the same physical properties as the base metal, assuring a strong positive connection with increased resistance to flash over-damage.



FOURTH PLACE LINCOLN AWARD

This tree planter brought a fourth place award to John Reed and Richard Rumph of West Plains, Mo., in the vocational agriculture division of this year's $15,000 national high school welding contest sponsored by the James F. Lincoln Arc Welding Foundation. Stand-ins for Reed and Rumph, now in the Armed Services, are (standing) Steve Douglas, shop instructor of the West Plains High School, and Charles Kenslow, president of the West Plains Future Farmer Chapter

Fourth CABRA Awards Program

Engineers, designers, manufacturers, architects and just about anyone associated with the use of copper, brass, or bronze are invited to enter the 1962 Copper and Brass Achievement Awards Competition, now getting under way. The contest will be the fourth annual event sponsored by the the Copper & Brass Research Association to honor outstanding new developments in the use or application of the copper metals in the U. S.

First prize awards of $500 and bronze trophies will be given for the best entries submitted in two categories: industrial and architectural.

Entry forms providing full details about the award program are available from the Copper & Brass Research Assn., 420 Lexington Ave., New York 17, N. Y.

Airco Distributor Installs Liquid Oxygen Station

O. E. Meyer, Jr., vice-president of O. E. Meyer & Sons, Inc., recently announced the opening of a new liquid oxygen storage and conversion station at the company's main branch in Sandusky, Ohio.

The new station will permit more efficient distribution of oxygen in both liquid and gaseous form to hospitals, metal fabricators and other industries.

M&T—Udylite Announce Merger Proposal

H. E. Martin, chairman of M&T Corp., New York, N. Y., and L. K. Lindahl, chairman of Udylite Corp., Detroit, Mich., recently announced approval in principle by both boards of directors of a merger between the two firms.

The Udylite Corp. manufactures a complete line of automatic plating machines, rectifiers and plating accessories.

New Rankin Distributors

Rankin Manufacturing Co., Alhambra, Calif., manufacturers of Ranite, Ranomatic and Tractormatic hardsurfacing electrodes and wires, has announced the appointment of four new distributors: Federal Equipment Eastern Ltd., Montreal, Que.; Interstate Welding Sales Corp., Marinette, Wis.; R & R Welding Supply Co., Rock Island, Ill.; and Southwestern Illinois Supply Co., DeSoto, Ill.

STULZ UNIVERSAL HARDFACE
WELDING ELECTRODES

The Finest Available!

STULZ UNIVERSAL HARDFACE

Reduces need for inventory of a variety of hardfacing. All-purpose electrode used in heavy industry and mining where varying conditions of abrasion, impact and metal-to-metal wear occur. Rapidly self-hardens up to 53 R.C. Low hydrogen type. Forgeable. AC-DC

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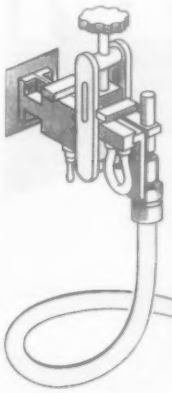

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Let you take work coils directly to work itself! All leads, including circulating water, completely self-contained. Lengths up to 20 ft.; longer lengths with couplers.

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PERSONNEL

Welding Research Council Names L. S. Wilcoxson

L. S. Wilcoxson, vice-president of the Babcock & Wilcox Co.'s boiler division, has been elected Chairman of the Welding Research Council—Engineering Foundation, for a three year period effective October 1. He has been vice-chairman of the Council for the past three years.

Born in England and now a naturalized American citizen, Mr. Wilcoxson received a Bachelor of Engineering Degree in 1922 from the University of Liverpool. He joined B&W in 1926 as a mechanical engineer, and was promoted to executive assistant in 1931. Mr. Wilcoxson was elected vice-president in charge of research and development in 1945 and undertook the establishment of the company's Research Center, at Alliance, Ohio. He attained his present position in 1955, with responsibility for all sales, engineering and manufacturing for the boiler division.

Leslie S. Wilcoxson

Airco Appoints Calhoun

The appointment of R. B. Calhoun AWS as assistant manager of distributor sales for the Pittsburgh district was recently announced by the Air Reduction Sales Co., New York, N. Y.

In his new post, Mr. Calhoun will be responsible for the marketing of Airco products through authorized distributors in Western Pennsylvania, Southeastern Ohio, Northern West Virginia and Western Maryland.

Mr. Calhoun first joined Airco in 1953 as a sales trainee in the metropolitan N. Y. district and later appointed a dealer representative in the Buffalo district in 1958 before being promoted to supervisor of distributor sales, a position he held until his present promotion.

Linde Appoints Walmsley

J. T. Walmsley AWS has been appointed Denver area manager for the Distributor Products Department of Linde Co., Div. of Union Carbide Corp. He will be responsible for coordinating marketing activities between a group of welding supply distributorships and the Linde region office in Kansas City, Mo. The area covered in Mr. Walmsley's new assignment includes Colorado, Wyoming, Western Kansas, Nebraska and part of New Mexico.

Harnischfeger Appoints Manager

Donald C. Helton AWS has been named manager of the Milwaukee district office for the Welding Products Div. of Harnischfeger Corp. of Milwaukee, Wis., according to W. R. Stephens AWS, sales manager.

The district will include all of Wisconsin and the Upper Peninsula of Michigan.

Mr. Helton has most recently

J. T. Walmsley

R. B. Calhoun

Donald C. Helton

Charles B. Culbert

Will G. Brooks

• For improved
MIG welding to 200 amperes...

GLENN CV200

Single-Phase
Constant-Voltage DC Power Supply

Model CV200 is only 19" wide x 25½" deep x 31" high; weighs 375 lbs.

Under development and field testing for the past 1½ years, the GLENN CV200 Single Phase power supply offers the finest performance available today in MIG power supplies of comparable rating.

Exclusive GLENN circuitry (patent pending) is designed especially to provide the correct volt-ampere slope for gas-shielded, wire-fed arc welding — including the entire range of short arc welding and spray-arc up to 200 amperes.

Other advantages include:

- **SINGLE-PHASE INPUT** at 230 or 460v — no costly special wiring required.
- **LOW INPUT** — only 17 amp at 460v or 34 amp at 230, at full rated load.
- **SIMPLIFIED CONTROL** — set the desired voltage on the vernier dial and you're ready to weld. Balanced constant-voltage circuit automatically provides correct volt-ampere slope for MIG welding at its best.

Rated output is 200 amps at 30 vdc, 100% duty cycle. Open circuit output voltage range is 8.5 to 53 on 230/460v input.

Because of its compactness, low initial cost and ease of installation, the GLENN CV200 makes the benefits of MIG welding practical and possible for many new applications. Why not get the facts now? Write today for literature, prices.

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INDUSTRIAL POWER SUPPLIES
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MID-WEST OFFICE: 644 South York • Elmhurst, Illinois
EASTERN OFFICE: 615 Riverwood Avenue • Point Pleasant, New Jersey

7

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served as contact metallurgist, traveling the entire U. S. as consultant on his firm's P&H welding machines and rods. Also, his appearance as guest speaker before many welding societies throughout the nation has earned him industry wide recognition as an outstanding authority in his field.

Culbert Named Sales Manager

C. B. Culbert, Jr., AWS has been named Eastern district sales manager for the Welding Products Div. of the McKay Co.

In his new position at McKay's New York office, Mr. Culbert will be responsible for the sales and service activities in the Northeastern States area for the company's full line of mild, stainless, low hydrogen, hard surfacing electrodes and wires.

Brooks Named Staff Engineer

W. G. Brooks AWS has been appointed staff sales engineer, Automatic Welding Div., Hobart Brothers Co., Troy, Ohio, as announced recently by John H. Headapohl, division manager. Mr. Brooks attended Western Reserve University and has held sales, engineering and management positions with various Cleveland firms.

Smith Appoints Kanak

Richard C. Kanak of Arlington Heights, Ill., has been appointed Territory Manager for Smith Welding Equipment Division of Tescom Corp. in the Chicago-Milwaukee area. The division of the Minneapolis firm manufactures gas torch and regulation equipment for distribution nationally.

Raymo Named to Bendix Post

Arthur J. Raymo AWS has been appointed director of manufacturing for the Kansas City division of The Bendix Corp., recently announced by E. E. Evans, general manager of the division.

Before joining Bendix, Raymo was factory manager for the Baldwin-Lima-Hamilton Corp. in Philadelphia. He has held major management positions in engineering and manufacturing, including the position of manufacturing consultant with the General Electric Co., Atomic Power Equipment Dept. in California.

Sykora Fills New Staff Post

George E. Sykora has been appointed to the newly created position as manager of standards and quality control, Instruments Div., The Budd Co., in an announcement by Dr. J. H. Buck, vice-president and general manager.

Mr. Sykora came to The Budd Co., Philadelphia, Pa., from Hoffman Military Products Div., Hoffman Electronics Corp., Los Angeles, Calif., where he was reliability engineer for military products.

In his new position, Mr. Sykora will be responsible for all standardization and quality control functions of the Instruments Div.

Allis-Chalmers Appointments

The Allis-Chalmers Manufacturing Co., Milwaukee, Wis., has announced the appointment of E. R. Danielson as assistant manager for the firm's processing machinery department. A-C West Allis Works has named J. E. Brinkmann, general superintendent, electrical departments, who succeeds W. C. Krecklow, recently named as consultant after almost 50 years with the firm. Allis-Chalmer's Pacific Region—San Francisco office has appointed J. F. Fenske as manager of motor sales; and R. E. Goodwill has been named sales manager of the A-C Norwood (Ohio) Works electrical department.

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Send resume stating salary requirements to **Harry A. Stone, Lycoming Division of Avco Corporation, 550 Main Street, Stratford, Connecticut.**

Finch Joins Miller Electric

A. R. Finch has joined the advertising staff of Miller Electric Manufacturing Co., Appleton, Wis., according to a recent announcement by J. G. Waldron, advertising manager. Prior to affiliating with Miller Electric, Finch was assistant advertising manager of Western Condensing Co. in Appleton.

Airco Elects Director

Andrew Kaul, III, chairman and chief executive officer of Speer Carbon Co., Inc., a subsidiary of Air Reduction Co., Inc., was elected a director of Air Reduction, in a recent announcement by J. A. Hill, president of the parent firm. Mr. Kaul's offices will be at Speer's headquarters in St. Marys, Pa.

Allis-Chalmers Appoints Five

The Allis-Chalmers Manufacturing Co., Milwaukee, Wis., recently announced the following appointments: T. D. Lyons, vice president—administration, Industries Groups; Will Mitchell, Jr., director, Research Div.; W. S. Pierson, comptroller; E. A. Spika, assistant comptroller; and Donald J. Powers, resident representative in Fort Wayne, Ind.

M&T Appoints Eight

Four group vice-presidents have been appointed by Metal & Thermit Corp., according to H. E. Martin, chairman. H. E. Hirschland has been designated group vice-president with the commercial development and research divisions; B. W. Weber, group vice-president in charge of the manufacturing, employee relations and administration divisions; J. L. Oberg, group vice-president in charge of the minerals, ceramics and welding divisions; and D. W. Oakley, group vice-president for the chemicals, coatings and plating divisions.

Three executive appointments were announced: L. W. Mawhinney, vice-president; R. A. Bernabo, corporate secretary; and E. J. Robesch, assistant controller and assistant secretary.

According to an announcement by C. H. Carpenter, Jr., Dr. Alexander Ross has been appointed European technical representative in Zug, Switzerland.

Alloy Rods Names Woods

Appointment of Gorham W. Woods AWS as research engineer has been announced by J. O. Cavanagh AWS vice-president in charge of research, Alloy Rods Co., York, Pa.

Vogt Named Vice President

John N. Vogt AWS has joined Temperature Engineering Corp., Riverton, N. J., as vice president in charge of manufacturing.

Mr. Vogt also affiliated with the American Society of Safety Engineers, served with the General Electric Co., pioneering some of the most notable advances in silicon rectifier manufacturing equipment and tooling and in the establishment of quality control standards for the semiconductor industry.

One of Mr. Vogt's leading responsibilities will be to insure that growing production facilities continue to turn out a product worthy of the Tempcor trademark.

Amax Appoints Technical Manager

In a recent announcement by A. E. Beck, president of Pyron Co., Div. of American Metal Climax, Inc., New York, N. Y., Frank Wills has been appointed technical manager. He will be responsible for expansion of the firm's metal powder business through the development of new product lines and existing processes.

In 1955 and 1956, Mr. Wills served a tour of duty at Brookhaven Laboratories as guest scientist on loan from Amax to the Atomic Energy Commission. Upon his return to the firm, he was staff metallurgist in the technical department of the company's Amco division.

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NEW... THIN, FUSED DEPOSITS WITH CONTROLLED DILUTION
NEW... HIGH-SPEED, DROSS-FREE CUTS IN 5-IN. METALS

FOR MORE DETAILS... SEE PAGE 1310 OF THIS ISSUE

H. J. Steinmetz Retires

H. J. Steinmetz, manager of the Air Reduction Sales Co. branch office in Huntington, W. Va., retired October 1, after 27 years with the company.

Sellstrom Names Miles

Cecil Miles has been appointed southwestern factory sales representative for Sellstrom Manufacturing Co., Palatine, Ill., covering Texas, Louisiana, Arkansas, New Mexico and Oklahoma. Mr. Miles will call on key users of the firm's broad line of welding and safety products.

Langley Named Manager

Appointment of C. J. Langley AWS as manager of Air Reduction Sales Co.'s Philadelphia district has been announced by N. F. Moody, eastern regional sales manager. He succeeds R. H. Merriman to the post.

Mr. Langley, who attended Pennsylvania State University, first joined Airco in 1946; three years later he was transferred to the Philadelphia district where he served as an engineering service representative. Mr. Langley was appointed supervisor—technical sales and later became assistant manager—sales for the Boston district in 1953. He returned to the Philadephia district last year to become assistant district manager—a position he held until his recent promotion.

Babcock & Wilcox Names Rowand

In line with a concerted effort to expand its share of world power equipment markets, the Babcock & Wilcox Co. recently reported that a marketing department has been established within its boiler division, naming W. H. Rowand as vice-president.

Succeeding Mr. Rowand as head of the engineering department is G. W. Kessler, chief engineer. Named to posts in the new marketing department are F. E. Hutton, marketing manager; C. L. Marquez, manager of product planning and market research; W. D. Stevens, proposition manager; and D. R Wilson, as commercial manager.

Impagliazzo Honored

C. H. Wheeler Manufacturing Co., Philadelphia, Pa., and The Griscom-Russell Co., Massillon, Ohio, honored A. Michael Impagliazzo for 25 years' service with the affiliated companies, according to a recent announcement.

Mr. Impagliazzo joined Griscom-Russell's engineering department in 1936. Last January, he was transferred from his post as manager of Griscom-Russell's industrial engineering department to that of engineering manager of C. H. Wheeler.

Schumann Assigned to New Ambraze Post

Stanley V. Schumann has been promoted to the new post of sales promotion at American Brazing Alloys Corp., Pelham, N. Y. A graduate of Alfred University, Mr. Schumann will be responsible for the marketing, promotion and advertising of American Brazing Alloys Corp. and the entire Ambraze line.

Omark Manufacturing Appoints Lillig Manager

All United States manufacturing operations of Omark Industries, Inc., were centralized under a single Manufacturing Division as of June 1, with Everett Lillig, formerly production manager, as division manager, according to Edward P. Skralskis, executive vice president of the Portland, Ore. firm.

In his new post, Lillig will supervise and evaluate all engineering and production functions which affect the development, improvement and manufacture of Omark products.

Lillig came to Omark in 1954, having previously held engineering positions with Fibreboard Products and Co. and Iron Fireman Mfg. Co. He is a graduate of Oregon State University in mechanical engineering and has done advanced study at Johns Hopkins Institute.

Gevaert Appoints Maillard

The Gevaert Company of America, Inc., has announced the appointment of Claude Maillard as Manager of their Industrial Sales Department. In his new work, Mr. Maillard will be responsible for the sales of industrial x-ray films, recording materials, microfilm, magnetic tape, and scientific films and plates in the United States.

Prior to his appointment, Mr. Maillard was the Gevaert Denver district manager, in charge of all Gevaert sensitized photographic products in that area. Mr. Maillard has been associated with Gevaert for more than 16 years.

OBITUARIES

Lewis McDonald

Lewis McDonald AWS, retired vice-president of Chicago Bridge & Iron Co., died October 20 at Chicago, Ill. He was 77 years old.

Mr. McDonald's career with CB&I spanned more than forty-four years prior to his retirement in 1954. He was manager of the company's Chicago sales district from 1921 to 1931 and served as assistant to the board chairman prior to his election as a vice-president in 1946.

Mr. McDonald served as president of the Chicago Engineers Club in 1939. He was a life member and past director of the University of Illinois Alumni Association. He was president of the Chicago Illini Club in 1949. He also held membership in the University Club, American Society of Civil Engineers and Western Society of Engineers.

Cecil C. Peck

Cecil Cressy Peck AWS passed away October 23, 1961, at his home after a long illness. He was 73 years old.

He was a graduate of Worcester Polytech Institute from which he held an engineering degree and later took graduate work in engineering at the University of Wisconsin. A registered engineer, Mr. Peck held many patents and was widely known as a pioneer in the automatic welding field. In 1935 Mr. Peck founded the Cecil C. Peck Co. as designers and builders of automatic welding equipment and was president and board chairman of that company until his death.

Cecil C. Peck

Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents
may be obtained for 25¢ from the
Commissioner of Patents, Washington, D. C.

2,950,377—Metal Arc Welding—Kenneth L. Thomas, Indianapolis, Robert J. Wickham, Plainfield, and George M. Skinner, Indianapolis, Ind., assignors to Union Carbide Corporation, a corporation of New York.

The present patent relates to the sigma welding of carbon steel and in which the welding arc and the adjacent metal are shielded from the air by an atmosphere composed of a mixture of carbon dioxide and oxygen in which the oxygen is between 5 and 50% of the atmosphere. A bare metal electrode is also used and it is made of deoxidized carbon steel containing residual deoxidizers.

2,950,378—Slide Closure for Welding—Roger W. Tuthill, Mountainside, N. J., assignor to Air Reduction Company, Incorporated, New York, N. Y., a corporation of New York.

Tuthill's patent is on welding equipment including a receptacle for enclosing work parts to be welded. A removable enclosure means is provided for the receptacle, and flexible stringers are also provided extending across the receptacle. A slider member is mounted on the stringers and a welding torch is carried by the slider and adapts it to extend into the receptacle for weld action.

2,950,380—Slag-Forming Bodies for Electric Arc Welding—Willem Pieter van den Blink, Utrecht, Netherlands, assignor to North American Philips Company, Inc., New York, N. Y., a corporation of Delaware.

This new slag-forming body includes slag-forming material and means for increasing the mechanical strength of the body. Such means include particles of synthetic mica distributed throughout the material.

2,950,381—Welding Electrode Feeding Apparatus—Ronald F. Brenne, 964 E. 16th St., and James A. Bucci, 2360 McDonald Ave., both of Brooklyn, N. Y.

The present patent relates to a specialized mechanical apparatus for controlling the feed of welding electrodes.

2,951,000—Welding Composition—Harry E. Kennedy, Berkeley, Calif., and Gerard E. Claussen, Summit, N. J., assignors to Union Carbide Corporation, a corporation of New York.

In this patent, a powdered magnetizable welding flux is disclosed. This flux comprises a specified percentage of zircon sand, magnesia, rutile, iron powder, and with the remainder of the flux being made from a group of materials including cryolite, silica, alumina and other substances.

2,951,143—Arc Torch—John E. Anderson and Thomas B. Reed, Danville, Ind., assignors to Union Carbide Corporation, a corporation of New York.

A high pressure arc torch is patented to Mr. Anderson and Mr. Reed by this patent. In the torch, a nozzle with a gas supply means connected thereto is provided for gas discharge through the nozzle, and a refractory metal preferential electrode is associated with the nozzle. A stick electrode is present within the body of the arc torch, the preferential electrode being mounted in the nozzle so that, while arc current is conducted through the nozzle to the preferential electrode, the thermal contact therebetween is relatively poor to cause the preferential electrode to operate at a substantially higher temperature and thus become more attractive as an arc terminal than the nozzle per se.

2,951,144—Article Forming Apparatus—Edward A. Heckman and Samuel Kuba, Allentown, and Richard C. Shafer, Emmaus, Pa., assignors to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York.

This is a patent on a specialized apparatus for securing predetermined lengths of a metallic strand to the outer ends of leads extending longitudinally from articles when in an operating position. The engagement is obtained by combined pressure and heating action.

2,951,145—Method and Apparatus for Fabricating Honeycomb Core—Roy L. Anspach, Newport Beach, Calif., assignor to John J. Foster Mfg. Co., Costa Mesa, Calif., a corporation of California

Anspach's patent relates to a honeycomb core fabricating machine and includes a movable electrode, and a member for supporting a pair of corrugated core strips with their nodal areas in juxtaposed relationship. The one electrode is then adapted to be moved into engagement with only a nodal area of one of the strips to support said strip during a welding operation, and another electrode is engageable with only the nodal area of the other strip and adapted to traverse such nodal area to cause welding current to flow through the nodal areas between the electrodes.

2,951,931—Automatic Arc-Welding Process, Equipment and Electrode—Francois Georges Danhier, Anderlecht (Brussels), Belgium, assignor to La Soudure Electrique Autogene, S.A., Brussels, Belgium, a corporation of Belgium.

The present patent is on a process for automatic electric arc welding and it includes the step of striking an electric arc between the work and a bare, continuous fusible metallic electrode. This electrode has a shell containing a core composed of certain parts by weight of the coherent metallic portion of the electrode, and the core contains a granulated mixture of deoxidizers in certain proportions to the weight thereof. Slag forming materials are also present in the core in specified materials and percentages. In the method the arc is surrounded with an atmosphere of carbon dioxide and is moved with relation to the work.

2,951,932—Welding Apparatus—Edward A. Heckman, Allentown, and Richard C. Shafer, Emmaus, Pa., assignors to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

The combination with two machines for forming their respective subassemblies of articles and disposed adjacent each other and having holders for their subassemblies movable intermittently successively into a final assembling position is disclosed in the present patent. Electrodes are provided and are movable into engagement with respective metallic parts of the subassemblies at the final assembling position and weld power is supplied thereto automatically when the electrodes engage the parts as moved, by an intermittent movement action of their holders to the assembling position.

2,951,933—Machine and Method for the Manufacture of Studded Electrodes—George B. Erskine, R.D. 1, and Stanley J. Gartner, 75 Broad St., both of Emporium, Pa.

The present patent is on a specialized machine for the manufacture of studded electrodes having a body and one or more radially extending studs secured thereto. The electrode is mounted in a mandrel which is positioned for axial rotation to bring successive spaced locations about a circumferential path about the electrode body into a welding position at which time the machine is adapted to bring the studs into engagement with the electrodes to be welded thereto.

2,951,934—Welding Torch—Ralph Dieter Engel, Union, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

The patented welding torch includes an outer barrel, a nozzle secured to the lower end of the outer barrel, and an inner barrel assembly at least partially within the outer barrel and including an electrode contact tube terminating above the lower end of the nozzle. Other members in the assembly provide a path therein for circulation of the cooling fluid.

2,951,972—Control Mechanism for an Electric Arc Welder—Jesse W. Pomazal, Escanaba, Mich., assignor to Harnischfeger Corp., Milwaukee, Wis., a corporation of Wisconsin.

The present patent relates to an electric arc welder having welding electrodes, a line to said electrodes and controllable means for varying the current supplied through the line to said electrodes. The novelty of the patent resides in automatically controlling the buildup and decay of welding current across the arc. These control means are subject to the voltage across the line and the current in the line to actuate the controllable means in response to voltage and current conditions characteristic of stages in the welding cycle.

2,952,765—Equalizing Spot Welding Gun—Norman C. Droste, 3010 N. Atladena Ave., Royal Oak, Mich.

In the patented equalizing spot-welding gun, a supporting structure is mounted on a base for travel toward and away from a predetermined welding location for a workpiece. A first welding electrode holder is mounted on the supporting structure. Other means including a fluid pressure cylinder mounted on the supporting structure for travel therewith, a piston reciprocably mounted in the cylinder, and a second welding electrode holder mounted on the piston for travel therewith toward and away from the first welding electrode holder are present in the machine.

2,952,766—Blowpipe Type Sigma Torch—Thomas A. Craig, Port Reading; Kenneth E. Richter, Whippany; Thaddeus J. Wojciak, Elizabeth; and Edward Meincke, Summit, N. J.; assignors to Union Carbide Corp., a corporation of New York.

The patented structure relates to a gas shielded arc torch. This torch includes a handle with an electrode wire guide tube mounted in the handle and extending therebeyond. A gas manifold is provided at the handle end of the wire guide tube and it has a plurality of spaced longitudinally extending gas passages therein receiving the gas from the manifold. A contact tip is carried by the projecting portion of the wire guide tube, and a gas directing nozzle surrounds the contact tip and receives gas from holes provided in the guide tube.

2,953,673—Method of Joining Wires—George M. Bouton, Madison; Earl L. Fisher, Morristown; and Philip R. White, Murray Hill, N. J.; assignors to Bell Telephone Laboratories, Inc., New York, N. Y., a corporation of New York.

The patented method relates to producing an electrically conductive connection between two copper wires that are insulated with polyethylene. In the method, one end of each of the wires is contacted with the concave face of a steel disk having a special alloy coating thereon. Next the disk is heated to a temperature of approximately 850° F by an electric current passing therethrough to produce a puddle of molten metal on the disk which wets the wires and then the assembly is cooled to form the desired electrically conductive connection.

New Literature

Welding and Cutting Fire Protection in Garages

How to deal with the serious problem of welding and cutting fires in garages is detailed in a new publication of the National Fire Protection Association entitled, *Welding and Cutting in Garages*.

The NFPA report indicates that 16% of the garage fires studied were traceable to welding and cutting and almost two-thirds of these involved the mishandling of gasoline.

Case histories and photographs of actual fires demonstrate the many hazards connected with welding and cutting operations in both repair and sales-and-service garages. Ways to avoid the hazards are described in the text.

"Welding and Cutting in Garages" is the first in a new series of special hazard studies prepared by the NFPA Fire Record Department. Copies (NFPA No. HS-1, 12 pages, illustrated, 50 cents) are available from the National Fire Protection Assn., 60 Batterymarch St., Boston 10, Mass.

Resistance Welding Controls

The General Electric Co., Schenectady 5, N. Y., recently announced the availability of four different bulletins on resistance welding controls.

Bulletin GET-2683, 12 pages, gives application hints for users of resistance welding apparatus and furnishes electrical and mechanical information on standard components comprising the General Electric nonsynchronous welding control. Information presented enables users to select proper components for particular applications, determine electrical requirements and enclosure size.

Bulletin GEA-5945. An 8 page bulletin describing a welding control providing precise timing and transient-free operation for consistent, high quality welds. Describes application for spot, seam and bench-welder control and special accessories available.

Bulletin GEA-6408, 12 pages, describes a line of resistance welding controls for spot, flash, projection, butt and seam welding applications. It also describes compact, high capacity ignitron contactors and 1A, 3B and 5B timers which meet NEMA specifications.

Bulletin GEA-6593, 4 pages, gives information about plug-in function timer offering the user correct sequence control for all types of nonsynchronous welding from a single purpose gun welder to complex electrically or mechanically operated, automated machines or groups of welding machines.

For your free copy, circle No. 51 on Reader Information Card.

Hard Surfacing Powders

A new 8½ × 11 two-page illustrated two-color technical data sheet (No. T-5) describing No. 75 tungsten carbide hard-surfacing Sprayweld powder is now available from the Wall Colmonoy Corp., 19345 John R St., Detroit 15, Mich.

The new literature discusses properties and applications of No. 75 and gives recommendations for its use in overlaying a variety of base metals. Use of the alloy in the Sprayweld Process is discussed in detail. This discussion covers such topics as surface preparation, application of the powder, fusing the sprayed overlay and finishing the fused overlay.

For your free copy, circle No. 52 on Reader Information Card.

Brazing Alloys Comparison Chart

The American Brazing Alloys Corp., P. O. Box 11, Pelham, N. Y., has just published a new brazing alloy comparison chart. Listing AWS—ASTM designations, Ambraze alloys and other manufacturer's trade names; it also details all the important silver, copper and brass base alloys.

For your free copy, circle No. 53 on Reader Information Card.

Tilting Weld Positioners

The Aronson Machine Co., Inc., Arcade, N. Y., has announced the availability of "Positioning (Section 9)" by Charles N. Aronson. The 13-page booklet discusses the 90 deg forward and 45 deg rearward tilting type of welding positioner. Complete engineering details and comprehensive specifications are given on 40,000 to 350,000 lb capacity models.

For your free copy, circle No. 54 on Reader Information Card.

Liquid Oxygen Cylinder Described

A liquid oxygen cylinder with a capacity of 3000 cu ft of oxygen is described in a booklet now available from Linde Co., Division of Union Carbide Corp., 270 Park Ave, New York 17, N. Y. The large capacity Linde LC-3 cylinder supplies the equivalent of 12 "K" type high-pressure cylinders. Yet the cylinder's weight is only 463 lb and it requires only ⅓ the space in storage or operation as its equivalent in high-pressure cylinders. The compact LC-3 delivers 300 cu ft of oxygen per hour at pressures up to 75 lb per sq in. Because of its relatively light weight and large capacity, the LC-3 is ideal for use whenever more than 5000 cu ft of cylinder oxygen per month is consumed. The LC-3 meets all ICC safety specifications and can be shipped over highways in any type of common carrier.

In addition to the LC-3 liquid oxygen cylinder, similar cylinders for use with liquid nitrogen and liquid argon are described.

For your free copy, circle No. 55 on Reader Information Card.

Metallurgical Products

The Foote Mineral Co., 18 W. Chelton Ave., Philadelphia 44, Pa., has issued a new catalog of products which lists lithium chemicals, metal and minerals, electrolytic manganese, zirconium, welding grade products and steel addition agents for applications in the chemical, metallurgical, mining, ceramic, electronic, nuclear and astronautic industries.

For your free copy, circle No. 56 on Reader Information Card.

Brazing Alloy Chart

A brazing alloy reference chart, listing metal compositions, density and melt and flow temperatures for silver brazing alloys and precious metal brazing alloys has been published by the Technical Service Dept., American Platinum and Silver Div., Engelhard Industries, Inc., 75 Austin St., Newark 2, N. J.

The chart details 37 Silvaloy

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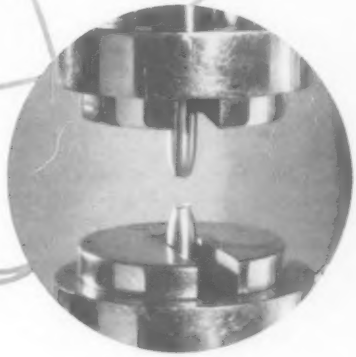
IN WELDING RESEARCH



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compositions, including all commercially important silver base alloys and many special purpose compositions. The 19 Engaloy precious metal compositions listed are ideal for atmosphere brazing and provide the higher brazing temperatures required for vacuum tube, aircraft and missile use; good corrosion resistance and minimum diffusion into base metals.

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Industrial Gases

Industrial Gas Data (Form ADE-890), a 48-page, pocket-sized booklet, providing industrial gas data in a compact, readily accessible form, is now available from Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y.

Bound in leatherette for durability, the booklet lists physical and chemical properties of oxygen, nitrogen, argon, helium, hydrogen, carbon dioxide, acetylene, neon, krypton and xenon. Similar information is included on the medical gases—ethylene, nitrous oxide and cyclopropane.

Handy conversion tables provide a simple and fast method for changing volumetric information on the various industrial gases from one equivalent unit of measure to another. Liberally illustrated with charts and diagrams, the booklet also provides capacity data on industrial gas delivery and storage systems.

For your free copy, circle No. 58 on Reader Information Card.

AEC Research Reports

A new edition of Atomic Energy Commission Research Reports, the semiannual price list of all unclassified AEC research reports for sale by the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce, Washington 25, D. C., has just been published.

The 50-page list includes more than 3500 AEC reports in the OTS collection as of July 1961. The new list may be obtained free by requesting AEC Research Reports Price List No. 36 from OTS, U. S. Department of Commerce, Washington 25, D. C.

Aluminum Coating Brochure

A new brochure, just published by Twin City Testing Corp., 533 S. Niagara St., Tonawanda, N. Y., introduces the Type EC Permascope for nondestructive measurement of (1) a nonconductive coating on a nonferrous base metal such as aluminum or copper, (2) a nonferrous coating on a nonferrous base, (3) a nonferrous coating on a nonconductor, and (4) conductivity of a nonferrous metal.

As well as containing descriptive information, specifications and prices for the new instrument, the brochure includes details on Type ES Permascopes for gaging coatings on iron and steel plus a technical discussion of nondestructive thickness testing.

For your free copy, circle No. 59 on Reader Information Card.

Pipe and Strip Heaters

Controlled, concurrent heat treating for welding high performance steels, using an improved system of safety-engineered plug-in pipe and strip heaters, is described in a four-page bulletin by J. B. Nottingham & Co., Inc., 441 Lexington Ave., New York 17, N. Y.

Weldments of almost any size or shape, including pipe down to 3-in. diam, may be heat treated with systems readily assembled from standard "Duraline" heaters, automatic controls and distribution equipment. Welders may work while heaters are in operation, automatically holding the parent metal at preset temperatures.

Personnel and equipment are fully protected by built-in fuses, equipment-grounded circuits, and molded neoprene - insulated construction that prevents accidental contact. Even unskilled help can quickly connect these interchangeable units, which may be used on job after job.

For your free copy, circle No. 60 on Reader Information Card.

Corrosion Resistance of Steels

A new 60-page booklet entitled, *The Role of Molybdenum and Copper in Corrosion Resistant Steels and Alloys*, has been published by Climax Molybdenum Co., Div. of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N. Y.

Containing numerous tables, charts, graphs and photographs, the new booklet describes the development of corrosion resistant steels based on the use of molybdenum, copper and nickel, together with sufficient chromium to retain, in large measure, the resistance to oxidation provided in the familiar chromium and the austenitic chromium-nickel (18–8) types of stainless steel.

The new booklet begins with the corrosion resisting properties of the constituent metallic elements themselves and proceeds to show how investigators have put these elements together in various combinations to achieve specific degrees of corrosion resistance in the resultant alloys. Special emphasis is placed on the economic and technological benefits of selecting the proper alloy.

For your free copy, circle No. 61 on Reader Information Card.

Brazing Stainless Steel

Brazing Stainless Steel—How to Make the Most of It is the title of a new 4-page bulletin recently available from Handy & Harman, 850 Third Ave., New York 22, N. Y.

The bulletin, also identified as *Brazing News No. 85*, describes several applications involving stainless steel wherein brazing easily solved specific problems.

For your free copy, circle No. 62 on Reader Information Card.

Portable X-Ray Units for Piping

The Use of Portable X-Ray Equipment in Pipeline Construction in a new Technical Bulletin No. 6 has been issued by Balteau Electric Corp., 10–14 Meadow St., Stamford, Conn.

Included in the illustrated literature is a detailed description of the application of radiography in pipeline construction work along with complete data dealing with actual X-ray techniques employed.

For your free copy, circle No. 63 on Reader Information Card.

Bench Model Spot Welding Units

Bulletin 130 describing 4.6 kva, 220- or 440-v bench model spot welding units with a capacity to spot weld from 16 to 30 gage mild steel, CRS, stainless steel, galvanized, etc., is available from Birdsell Products, 350 N. Halstead, Pasadena, Calif.

The 220-v, single phase, 50/60 cycle standard spot welding unit has a heavy duty contactor and electronic timer to prevent the possibility of burning work and for greater efficiency and economy in welding. Current control with electronic timer settings 3 to 30 cycles. Heat control settings 1 to 5. Welding current at tips from 4000 to 7000 amp and squeeze pressure up to 400 lb. These units are approved by Underwriter's Laboratories, Inc., and meet REA and NEMA specifications.

For your free copy, circle No. 64 on Reader Information Card.

Welding and Brazing Alloys

A new catalog has been released by All-State Welding Alloys Co., Inc., 249–55 Ferris Ave., White Plains, N. Y. This compact 4½ page folder provides a handy and authoritative reference to specialty products for welding, soldering and brazing.

Alloy selection charts and convenient product groupings are designed for time-pressed welders. Fluxes are featured in a special section and a new No. 430 stainless solder kit is described. Other sections cover the electrodes for cast iron welding, a broad range of copper and bronze alloys for welding and brazing, Spoolarc alloys for aluminum welding and a product grouping for solders and silver alloys.

New products featured in the catalog are a silver brazing alloy with the extrusion coating which does not chip nor char and improved bronze alloys with microground flux coating. Spoolarc processing of welding alloys has also expanded to a new group of copper alloys, silicon bronze, deoxidized copper, aluminum bronze, phosphor bronze and the exotic metals—titanium, beryllium, magnesium, etc.

For your free copy, circle No. 65 on Reader Information Card.

Bending Plastic Sheets

A new plastic heating device is described in Bulletin 61-3 available from Kamweld Products Co., 932 R Washington St., Norwood, Mass.

The bulletin includes information of types of plastics suitable for bending, operating instructions for single, double and extra wide bends. It also states methods of heating polyethylene and polypropylene for bending. Time-and sheet gage specifications charts are listed for various plastic sheets.

For your free copy, circle No. 66 on Reader Information Card.

Industrial Catalog

Allied Electronics Corp., 100 N. Western Ave., Chicago 80, Ill., has announced release of a 592-page, 1962 catalog, largest in Allied's 41-year history as an electronic parts distributor to industrial and consumer markets. All items are listed at factory prices with the same quantity discounts offered by the original equipment manufacturer.

For your free copy, circle No. 67 on Reader Information Card.

Foreign book reviews are by G. E. Claussen, contributor to the World Wide Welding News column.

Welding Engineering (Lehrbuch Der Schweisstechnik), Vol. 1, Arc Welding Processes by Carl G. Keel, 392 pages, 448 illustrations, published in 1961 by Birkhauser Verlag, Basel, Switzerland.

This is the twenty-second volume in the publisher's series of text books and handbooks of engineering science. The author is director of the Swiss Welding Society and editor of its monthly welding magazine. He is also a lecturer at the Federal Technical College in Zurich, Switzerland.

The book is in German and is divided into a survey of welding as a whole and arc welding processes. Following a 35 page discussion of electric and magnetic characteristics of the arc and metal transfer, there is a 60 page exposition of generators, rectifiers and transformers. The relation of power supply design to static characteristics is well explained, particularly for Silicon rectifiers. Another 35 page section deals with manipulative techniques of electrodes by operations in, for example, vertical welding.

The longest chapter (115 pages) is devoted to covered electrodes and is one of the best comprehensive surveys of the subject in existence. Electrode manufacture, covering compositions, metallurgy of weld metal and deposition rates are the principal topics.

The final chapter (70 pages) on automatic welding includes various processes employing covered electrodes, submerged arc, steel and electroslag processes. There is a brief discussion of adjusting automatic welding machines but almost no information on gas metal-arc, gas tungsten-arc and CO_2 processes.

The book fills an important gap in the survey type of engineering textbook. As the author states, "Welding information is scattered over thousands of papers and reports but there are very few good resumes in book form." Certainly his is one.

STULZ SPRAY-ROD
THIN LAYER HARD SURFACE
WELDING ELECTRODES

The Finest Available!

STULZ SPRAY-ROD

For "spray on" layers of hardfacing. Goes on fast! Hard, smooth skin to protect all steels against abrasion. Fine for edge-facing where section is important. AC-DC

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STULZ-SICKLES COMPANY
929 JULIA ST. • ELIZABETH, N. J.
producers of famous manganal steel products

For details, circle No. 36 on Reader Information Card

Plan now to be at
the AWS 43rd
Annual Meeting!!

Now you can check
WELD TIME with
new PORTA-COUNT
cycle counter

only $282

Counts actual weld time during firing. PORTA-COUNT is light and small enough to carry easily—keep right on the job. Completely portable and self-contained with long life (up to 2 years) batteries. Counts single phases.

No Plug In No Clips No Clamps

PORTA-COUNT uses an inductive pick up to count, sensing magnetic field around power line, welding buss, transformer or electrodes.

INSTRUMENT CONTROL CO.
2309 Snelling Avenue
Minneapolis 4, Minnesota

For details, circle No. 26 on Reader Information Card

New Products

Low-Cost Short Arc Package

A complete outfit for "Sigma" short arc welding, including power supply, has been introduced by Linde Co., Div. of Union Carbide Corp., 270 Park Ave., New York 17, N. Y. The Sigma, which Linde asserts is the lowest-cost on the market, includes: compact wire-feed control unit with centrifugal governor; 200-amp power supply with variable voltage and inductance controls; 14-oz, 200-amp torch; shielding gas regulator-flowmeter; 12-in. wire-spool mount; torch service lines and 12½ ft of argon hose and control cable.

The 40-lb control unit, which can be removed from the power supply for field operation and ST-6 torch may be purchased separately. The

SWM-14 includes parts such as the regulator-flowmeter, which are not included in competitive machines, yet is priced from 1% to 12% below similar machines presently available, according to Linde.

Two power supplies are available, specially-designed for short arc welding: the basic unit has a continuously-variable inductor, the other has a two-value inductor (at slightly lower cost). Both are rated at 200 amp, 100% duty cycle, and cover the entire range for short arc welding with 0.030-, 0.035- and 0.045-in. wires. They can also be used for spray arc welding up to 200 amp with 0.030-, 0.035- and 3/64-in. wires.

The rugged, air-cooled torch has a 60° curved nozzle and rear-entry service lines for improved visibility, better balance and reduced weldor fatigue.

Separated from the power supply, the control unit reportedly can be operated in any position. Hooks are supplied for hanging in off-the-floor welding or where floor space is not available.

For details, circle No. 101 on Reader Information Card.

High-Pressure, Low-Volume Regulator

A new regulator for high pressure and low volume, made of solid bar stock, has been placed on the market by National Welding Equip. Co., 218 Fremont St., San Francisco, Calif. Two model types are available, one with a delivery range of from 0–1000 psi and the other one from 0–2000 psi.

The regulator is very compact, made of solid bar stock for maximum sturdiness and safety. The regulator is provided with two brass cased gages and an adaptor kit with 3/16 in. flexible, copper tubing with 1/8 in. Parker fitting and adapter bushing with 9/16 in.-R.H. thread for field change-over.

For details, circle No. 102 on Reader Information Card.

Plastic for Filling Crusher Cavities

Plastic pack, an epoxy resin compound for use in filling cavities between manganese wearing surfaces and structural steel member of crushers, is now available from the Allis-Chalmers Manufacturing Co., Milwaukee 1, Wis.

The resilient, nonshrinking compound does away with the need for elaborate application preparations associated with zincing. Easy to pour, it can be applied at the crusher site. It has a maximum compressive strength of 16,000 psi.

Plastic pack is poured as a filler into the space between the head and mantle or top shell and concave ring.

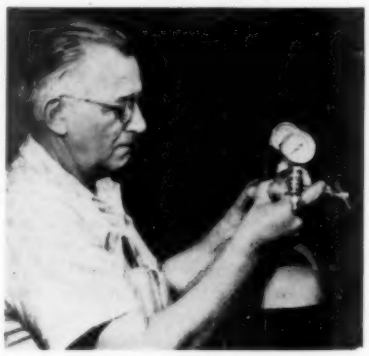
An 11-lb Plastic pack kit will fill the same area as 52 lb of zinc.

For details, circle No. 103 on Reader Information Card.

Inverse-Seat Gas Regulators

A new series of all-purpose, single-stage industrial gas regulators—featuring inverse type seat design—has just been announced by Air Reduction Sales Co., 150 E. 42 St., New York 17, N. Y.

With this new design, the Airco 9100 Series oxygen and acetylene regulators provide slightly rising



delivery, or work pressure, as cylinder pressure falls off. This makes possible lower residual pressures at cylinder and points than is attainable with a conventional single-stage regulator. Through a unique diaphragm design, the excellent performance of a large diaphragm area is provided without making the regulator body excessively large.

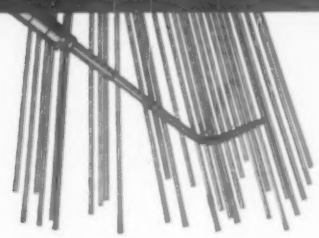
Other operating advantages offered by the Airco 9100 Series regulators are rugged construction, simplified maintenance and extended life. The new regulators are available in five models for use in welding, cutting, brazing and heating operations.

For details, circle No. 104 on Reader Information Card.

Fail/Safe Test Electrodes

For instant identification of welding electrodes used on critical work, such as nuclear components, Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa., offers a 100% inspection and high visibility marking of individual welding electrodes. Each electrode is subjected to a fail/safe test—in facilities isolated from all other manufacturing activities. Each electrode passed as "safe" is marked with the appropriate AWS grade designation in legible characters at frequent intervals lengthwise on the electrode. The marking is not affected by welding heat so that any unused portion of an electrode remains identified.

TITAN quality metals for the welding industry



BRONZE WELDING RODS

Titan bronze welds are dependable in service, have high strength, toughness, excellent wear resistance. Welds are made easily and quickly to cast, malleable and wrought iron, most steels and many copper-base alloys. Because of their facility in permanent braze welding of so many metals, Titan welding rods are widely used in repair operations and in production welding of metal assemblies.

EXTRUDED BRASS SHAPES

Manufactured to your exact requirements, Titan special brass shapes give highest production, elimination of scrap parts and unsurpassed machinability.

BRASS & ALUMINUM FORGINGS

Hot-pressed to provide maximum density, high strength, long life, superior finished surface. Have thinner sections, closer tolerances and uniform free-machining advantages over sand castings.

BRASS & ALUMINUM MACHINED PARTS

Machining to close tolerances is a Titan specialty. You can cut costs and reduce assembly problems. Fast delivery is assured.

Established 1915

TITAN® METAL MANUFACTURING COMPANY
DIVISION OF CERRO CORPORATION

Bellefonte, Pa. • Newark, Calif. • Offices & Agencies in Principal Cities

RODS • FORGINGS • DIE CASTINGS • WELDING RODS • WIRE

Write for 6-page Welding Rod folder

For details, circle No. 27 on Reader Information Card

Arcos Fail/Safe tested electrodes are packaged in hermetically sealed cans with a highly visible identifying tape. The tape cannot be removed without leaving a tell-tale trace of its removal. For shipment, individual cans are packaged in cartons with distinctive markings and labeling.

For fabricators who do not require 100% fail/safe testing of each electrode, high visibility marking of each electrode can also be provided. Electrodes marked only with the applicable AWS grade will be packaged in the standard Electropak and shipping container.

For details, circle No. 105 on Reader Information Card.

Welding Machine/Power Plant

The AEA-200-L gasoline engine-driven welding machine/power plant is now powered by a special 15 hp air-cooled engine, according to Miller Electric Manufacturing Co., 119 North Douglas St., Appleton, Wis. Welding power output is increased to 250 amp—225 amp at 100% duty cycle. This model also provides 1 kw of direct current while welding

and, as a standby power plant, delivers 5 kw of 115/230 v alternating current for running household lights, refrigerator, appliances, etc.

New engine features include twin mufflers, automatic spark advance and rotators on all valves which, with valve seats, are now Stellite faced.

For details, circle No. 106 on Reader Information Card.

Solid Core Hard-facing Rod

Electric arc application of tungsten carbide hard facing has been improved by Kennametal Inc., Latrobe, Pa., by development of a new solid-core Kenface arc rod KT-200. This rod is particularly recommended for large pieces on which gas application is not practical.

The new solid-core arc rod is composed of a solid tungsten carbide core surrounded by a steel sheath with a coating that permits depositing a hard surface as smooth as that applied by a mild steel welding rod. The deposit flows on easily with an extremely low porosity and minimum of heat checking.

The arc rod is suitable for either bead or wash pass application. Although ac application is recommended, the rod can be applied by either ac-dc reverse polarity current (160-200 amp, 16-20 v). Rockwell

SHORT ARC

NEW... COMPLETE *SIGMA* SWM-14 OUTFIT AT A LOW PACKAGE PRICE—$1,475

LINDE's all-new SIGMA SWM-14 Short Arc package . . . *all the equipment you need* for welding thin-wall pipe, tubular structural members, all thin-gauge metals—without burnthrough. Short Arc welding uses tiny drops of metal, not a spray. Tolerates 100% gaps. All-position welding with uniform burnoff rate, pinpoint heat control, minimum distortion.

The SWM-14's only "economy" is its price—$1,475. All parts are heavy-duty and readily accessible. *Compare what you get:*

- Compact, detachable wire-feed control unit—with centrifugal governor—swivel-mounted on power supply.
- 200-amp power supply (100% duty cycle) with variable voltage and inductance.
- 14-oz., 200-amp, air-cooled torch for .030-, .035- and .045-in. diameter wires.
- Shielding gas regulator-flowmeter.
- 10 ft. of argon, wire-feed, and power lines.

For complete details . . . and a "live" demonstration . . . contact your local LINDE office or write direct.

LINDE COMPANY
Division of Union Carbide Corporation
270 Park Avenue, New York 17, New York

UNION CARBIDE

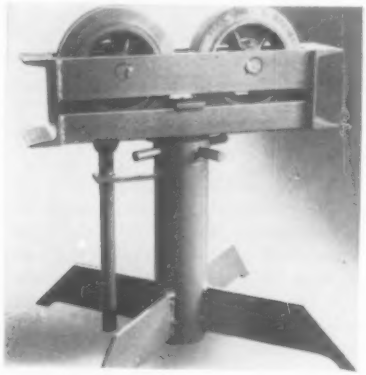
For details, circle No. 33 on Reader Information Card

C hardness of deposits ranges from 58 to 63 for a single pass and from 60 to 65 for double pass. Rods are $^{3}/_{16}$ in. in diam and 14 in. long. Coverage of $^{1}/_{8}$-in. thickness is 25 sq in. per pound of rod.

For details, circle No. 109 on Reader Information Card.

Adjustable Pipe Dolly

To facilitate the use of small welding positioners for rotating elongated cylindrical vessels and pipe, Aronson Machine Co. Inc., Arcade, N. Y., now offers the model APD adjustable pipe dolly for use as an outboard support in place of small tailstocks. This model will support 3000 lb on 6 in. diam rubber tired wheels (steel wheels optional).



The wheels are carried on anti-friction bearings. The fixed center-distance setting encompasses diameters of 2 to 24 in. (when used as outboard support the max diam is not limited). The adustable height base has 12 in. of adjustment with the adjusting screw type post guided and carried on an anti-friction bearing. The base adjustment allows quick changes in wheel height for various diameters of workpieces.

For details, circle No. 110 on Reader Information Card.

Rectifier Welding Unit

A new "Lowboy" silicon dc rectifier welding machine for arc welding, cutting or gouging is being announced by Hobart Brothers Co., Troy, Ohio.

A single dial controls the entire welding range of the machine which has no moving coils or cores. Optional remote control (either hand or foot operated) can be left connected to the machine and made operational by flipping the remote control switch on the control panel.

The low design and rigid construction permit stacking for parallel operation or to conserve floor space.

Silicon rectifiers are permanently sealed. A built in surge protector prevents the possibility of voltage pulses damaging the silicon rectifiers. Overload protection is also included.

This unit is available in two models with 60% duty cycle ratings of 200 and 300 amp.

For details, circle No. 111 on Reader Information Card.

Silicon-Bronze Welding Rod

A new silicon-bronze welding rod—suitable for use with the tungsten insert-gas, carbon arc and oxyacetylene welding processes—is now available as a standard item of Air Reduction Co., 150 E. 42nd St. New York 17, N. Y.

Designated Airco 1010, it is used for welding silicon bronze wrought and cast materials, as well as weldable grades of copper and copper alloys. In addition, Airco 1010 has many applications employing plain and galvanized steel.

The silicon-bronze alloy welding rods come in 36 in. lengths and diameters ranging from $^{1}/_{16}$- to $^{5}/_{16}$-in. The standard package is a 50 lb carton.

For details, circle No. 112 on Reader Information Card.

Portable Radioisotope Unit

A completely self-contained, portable radioisotope unit called the "Pipeliner" has been developed by Picker X-Ray Corp., White Plains, N. Y., for versatile industrial inspection ranging from atomic submarines to welded pipelines.

The Pipeliner, offering 10-, 20- or 30-curie power, can radiograph 2-in. thick steel (it handles 1-in. steel in less than a minute), Picker officials said. It uses Iridium 192 housed in a special lead-tungsten alloy as its radiation source.

The compact unit is contained in a rugged, weatherproof aluminum case that measures only 18 x 11 x 9 in. One man can carry it for field or in-plant inspection, as the head weighs only 35 lbs and the controls 25 lb.

For details, circle No. 113 on Reader Information Card.

STULZ MANGANESE-XL
WELDING ELECTRODES

The Finest Available!

STULZ MANGANESE-XL

For high-strength joining of dissimilar carbon and alloy steels. Excellent shock resistance. Porosity free. Easily cut by oxy-acetylene. Good vertical welding. Low hydrogen. Austenitic manganese-nickel analysis.

AC-DC

write for name of nearest distributor

STULZ-SICKLES COMPANY
929 JULIA ST. • ELIZABETH, N. J.
producers of famous manganal steel products

For details, circle No. 37 on Reader Information Card

Spot Surface Thermometer

Pacific Transducer Corp., 11836 W. Pico Boulevard, Los Angeles 64, Calif., announces the development of a spot surface thermometer. This new type of thermometer, with a range from 0 to 540° C, is made entirely of stainless steel. The thermometer may be used on any surface such as dies, hot plates, sheet metal, furnace skins, boilers, large superheated steam pipes, cooled billets, etc.

For details, circle No. 114 on Reader Information Card.

New Electron Beam Welding Machine

Alloyd Electronics Corp., 37 Cambridge Parkway, Cambridge, Mass., has announced an electron beam unit Model Mark VI, for the welding and brazing of refractory and reactive metals. The Mark VI has been successfully used for welding metals such as beryllium, ti-

LINDE ELECTRIC WELDING

PLASMARC

New...very-thin, fused deposits with controlled dilution
New...high-speed, dross-free cuts in 5-in. thick metals

LINDE, inventor of plasma arc processes, announces *new* PLASMARC weld surfacing and *advanced* PLASMARC cutting. What is plasma arc? It is a flow of gas forced through an electric arc, constricted in a small-bore torch nozzle, and accelerated to form an intense jet. It combines electrical heat with the latent heat of highly-excited ionized gas atoms to reach one of the highest known metal-working temperatures (30,000° F.). It will melt any known metal.

A TRUE WELD

PLASMARC *weld surfacing* is true welding—not coating or plating—achieved by feeding powdered metal through the plasma arc into a weld puddle which freezes to form the deposit. Its precision eliminates excess buildup—ideal for such parts as valves, plowshares, seals . . .

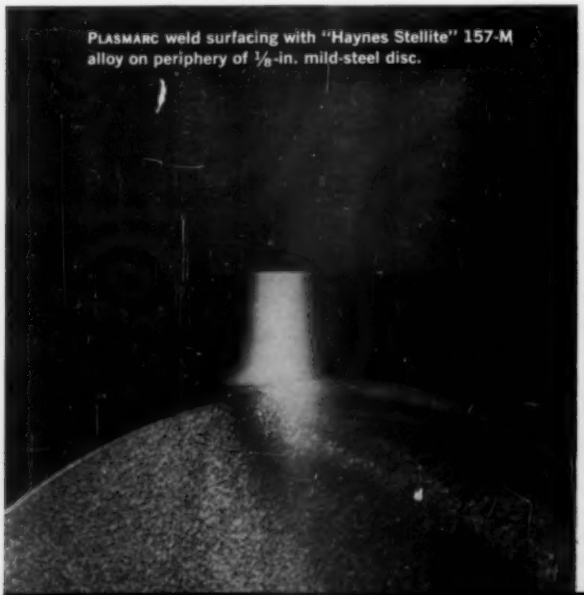
PLASMARC weld surfacing gives precise control of penetration of overlay metal into base metal—as little as .005 in. or higher. Gives precise control of dilution with base metal—from 5% up to 50%. Provides one-pass deposits as thin as .010 in., as thick as 3/16 in., with a wide range of metals and alloys. Produces widths from ⅛ in. to 1 in. or more, speeds over 20 ipm at 95% deposition efficiency, flatter and smoother deposits than other fusion processes.

4000 FT./SEC. VELOCITY

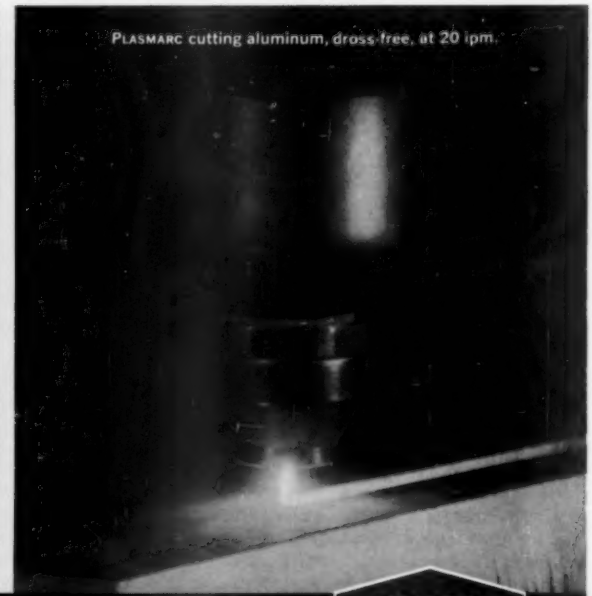
PLASMARC *cutting* uses a near-sonic velocity plasma jet (4000 ft./sec.). It easily melts-and-forces a narrow kerf through both ferrous and non-ferrous metals with little or no change in metallurgical properties. After six years' success, it is replacing shearing, sawing and powder cutting—slower methods which often require machining of the cut edge.

PLASMARC cutting has been further developed—heavy-duty equipment, higher current capacity—to handle increased metal thicknesses. It cuts aluminum, magnesium and copper up to 5-in. thick and stainless steel up to 2 in. thick, dross-free. It clean-cuts 4-in. thick stainless, nickel, carbon steel (requires no iron powder), "Monel," "Inconel," cast iron, high-alloy and clad steels. It makes precise, high-speed cuts up to 300 ipm, holds tolerances to 1/16 in., leaves a heat band as thin as .006-in. wide.

Get full details . . . see a "live" PLASMARC demonstration. Contact your local LINDE office or write direct.



PLASMARC weld surfacing with "Haynes Stellite" 157-M alloy on periphery of ⅛-in. mild-steel disc.



PLASMARC cutting aluminum, dross-free, at 20 ipm.

LINDE COMPANY
Division of Union Carbide Corporation
270 Park Avenue, New York 17, N.Y.

UNION CARBIDE

For details, circle No. 32 on Reader Information Card

tanium, tantalum, the company states.

The Mark VI is a complete system that includes electron gun, vacuum chamber, mechanical roughing and diffusion pumps, power supply and console. Material handling fixtures inside the vacuum chamber permit spot, longitudinal, annular and circumferential welds.

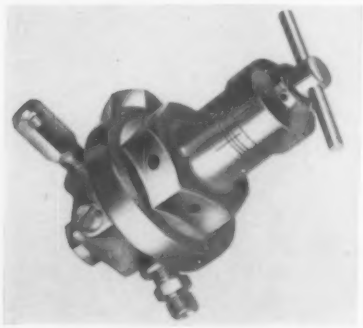
Mark VI controls can vary electron gun supply (0-20 kv, 0-300 ma), adjust filament, current bias and focus. Spot diameter can be continually controlled from 0.010-in. min. to an excess of 0.500-in. max.; focal length, from 4 to 12 in.

For details, circle No. 115 on Reader Information Card.

Gageless Regulator

An extremely accurate and sturdy, all metal, gageless regulator, for use with most pressurized liquids and gases, is now being offered by Dockson Corp., 3839 Wabash, Detroit 8, Mich.

Available in single stage and double stage models, the new gageless regulators effect sizable savings, not only in initial expenditure, but also in long range maintenance costs. They are considerably less susceptible to damage from blows or falls than the conventional glass-faced gage regulators.



The bonnet and body are constructed of solid forged brass. Carefully tested and individually calibrated adjustment scales are clearly etched on the bonnet of the regulator for permanent, easy reading. A simple turn of the "T" handle on the micrometer-type pressure regulator cap quickly sets and maintains the desired working pressure.

Tank pressure is shown by a special, positive-reading, damage proof, indicator rod which slides inside a hex plug. When the tank is full, the rod fills the viewing hole. As the tank empties, the rod retracts into the regulator body, until it disappears from view when the tank is entirely empty.

For details, circle No. 121 on Reader Information Card.

Portable Welding Equipment

A new type of compact welding equipment, intended for use in handicraft and small industry, has been added to the manufacturing program of Nohab, Trollhättan, large makers of turbines, diesel engines and locomotives, this Swedish company reports. The equipment includes portable arc welding transformers weighing 70 lb and occupying a space of only 2.7 sq ft.

Suitable for both light gage welding and heavy plate welding, it is possible to weld with normal electrodes of 1–4 mm diam and with basic electrodes of 1.5—3.25 mm. The air-operated spot welding tongs, weighing only about 28.6 lb, can weld up to 2 mm plates when using short arms and up to one millimeter when using long arms. They are operated either suspended from a fixture or mounted on a stand but can, owing to their light weight, also be used as a hand tool.

For details, circle No. 122 on Reader Information Card.

Interchangeable Flowmeter

National Welding Equipment Co., 218 Freemont St., San Francisco, Calif., has announced a new flowmeter incorporating instant interchangeability of calibrated pyrex tubes for all cylinder gases and flow capacities. This feature permits the distributor or the ultimate owner to exchange tubes to meet any requirement with a minimum of lost time. The calibrated pyrex tube may be turned in any desirable direction by simply removing the outer flowmeter shell.

For details, circle No. 123 on Reader Information Card.

STULZ PIERCING ELECTRODES

The Finest Available!

STULZ PIERCING ELECTRODES

STULZ-SICKLES COMPANY

For details, circle No. 38 on Reader Information Card

Symbols for Welding

Sq. Groove Weld Arrow Side | Sq. Groove Weld Other Side | Sq. Groove Weld Both Sides

Symbol of Quality

LENCO

CABLE CONNECTORS

Save wear on welding cables. LENCO Cable Connectors let you use just the amount of cable you need for the job. Add on cable—take off cable with ease. Made of high conductivity brass with tough Neoprene covers. Two sizes to fit all sizes of welding cable.

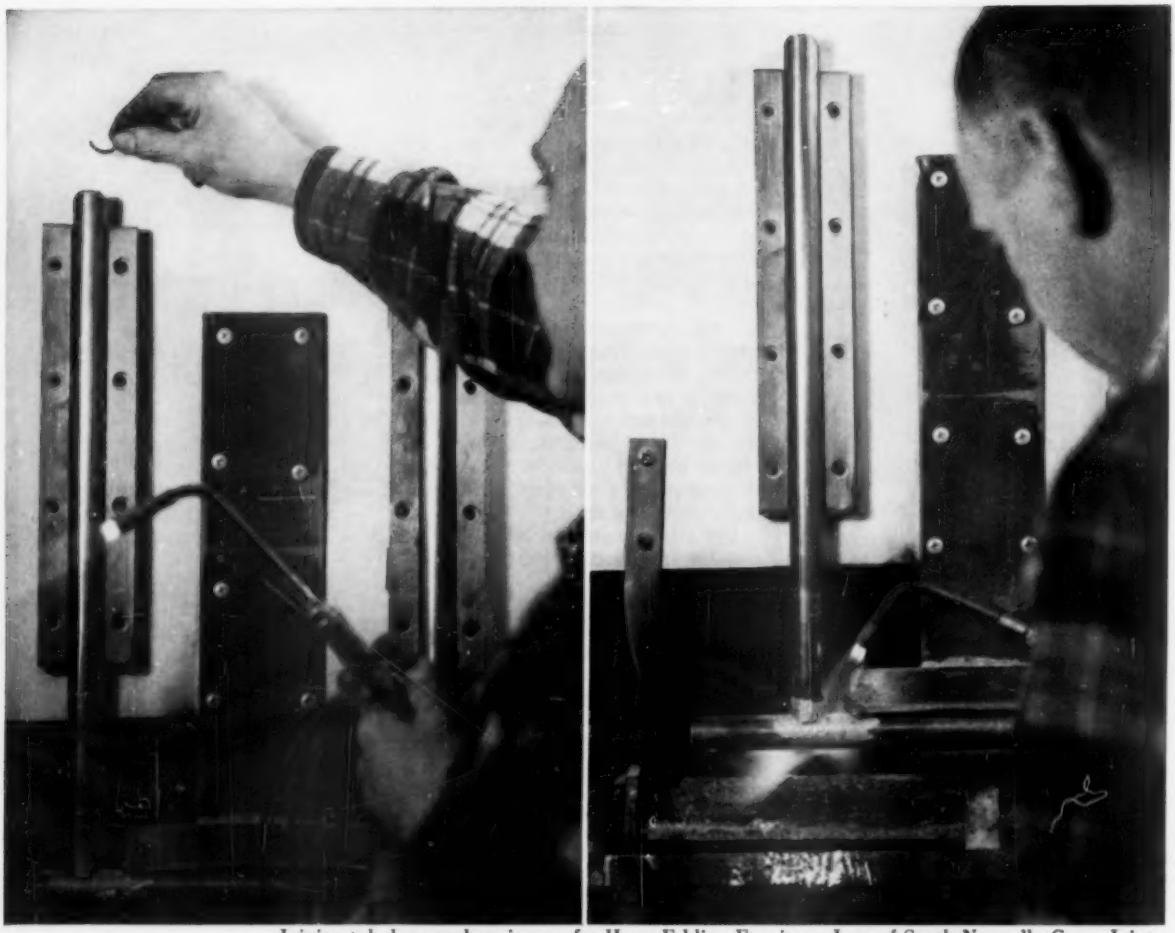
FREE Large 8½x11 chart shows symbols for arc, gas and resistance welding.

WRITE TO:

LENCO, INC.

350 West Adams Jackson, Mo.

For details, circle No. 28 on Reader Information Card



Joining tubular members is easy for Howe Folding Furniture, Inc., of South Norwalk, Conn. Joints are fluxed with Handy Flux, a half-circle preform of EASY-FLO brazing alloy is dropped down the tube and a torch is applied. Result: A smooth, strong joint quickly and economically made.

How Handy & Harman Brazing Alloys

GIVE FOLDING FURNITURE 100% JOINT RELIABILITY

The experience of Howe Folding Furniture, Inc., with silver brazing merits close attention if your operations involve metal-to-metal joining of any kind. Howe manufactures folding metal tables and seats for commercial, industrial and institutional use. You can imagine the hard usage the furniture has to take—yet survive indefinitely.

Some years ago, it was Howe's practice to purchase prefabricated steel tubular assemblies in which the joints were brass brazed on the outside surface. To improve their product, Howe thoroughly tested all joining methods, and decided to go over to silver brazing in their own plant, using Handy & Harman EASY-FLO Alloys 45 and 35. Look at the results:

Complete Joint Reliability: Since adopting silver brazing, Howe has completely eliminated the problem of broken joints.

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SUPPLEMENT TO THE WELDING JOURNAL, DECEMBER 1961

Fatigue Behavior of Welded Joints in Reinforcing Bars for Concrete

Fatigue strength is highest for 60 deg single-V butt-welded joints and ranges only 5 to 15% lower than for unwelded bar

BY W. W. SANDERS, Jr., P. G. HOADLEY AND W. H. MUNSE

SUMMARY. Fatigue tests were conducted on welded joints in No. 7 intermediate grade billet-steel reinforcing bars. The majority of the tests were conducted on 60 deg single-V butt-welded joints in unencased deformed bars. However, several tests were conducted on welded bars encased in concrete blocks. A number of tests were also conducted on unwelded reinforcing bars to study the effect of the welded joints on the fatigue behavior of the bars.

The fatigue strengths of the unencased welded reinforcing bars (60 deg single-V butt weld) were obtained for zero-to-tension, full reversal and partial tension-to-tension stress cycles; they indicate, for all stress cycles, reductions of less than 15% from the corresponding fatigue strengths of the unwelded parent material. A comparison of the fatigue strengths of several additional joint configurations is included also.

Introduction

During recent years, the apparent advantages of splicing reinforcing bars by welding have been recognized. Many questions have been raised, however, concerning the reliability and strength of the welded joints. Present ASTM specifications for reinforcing bars limit only the physical properties and the percentage of phosphorus. Because of the variations in chemical composition which are encountered, these specifications may provide a steel which could be rather difficult to weld.

Only limited data are available on welding reinforcing bar behavior upon which design recommendations can be based. The data from tests that have been conducted on welded joints in all grades of steel bars are almost entirely based on static loadings. These data[1] have shown that it may be possible, with proper welding procedures, to obtain about 90% efficiency in a laboratory welded joint under static conditions, regardless of the chemical composition of the bars. In many cases, however, the service loadings placed upon the welded joints are not of a static nature; instead they are of a cyclic nature.

Numerous cases can be found where welded reinforcing bars are more economical and satisfactory than lapped reinforcing bars. For example, many of the existing concrete bridges have had to be widened because of the large increase in the width, volume and speed of highway vehicles. Often, by removing sections beyond curbs and exposing the slab reinforcement, it has been possible to weld new bars to the existing reinforcement to economically obtain a continuous transverse structure. The connections of the old and new reinforcement, which are exposed to fatigue loadings during each vehicle passage, can better be made with welded joints rather than lap joints.

In recent years, the use of precast concrete bridge members has increased greatly. The economy of mass production has increased their use not only in new construction, but also in the replacement of damaged bridges. Because of the savings that can be realized in using continuous construction, welding reinforcement of adjacent precast elements and subsequently filling of the gap between the members with concrete can provide an economical means of obtaining continuity. Welding of the reinforcement is essential because of the excessive lap otherwise required to obtain full transfer of the tensile force.

With the amount of welding of reinforcing bars for concrete increasing rapidly in structures where repeated loadings are applied, it is desirable to determine the proper connection details and the strength of the welded joints in bars which are subjected to fatigue loadings. Approximately 70 fatigue tests have been conducted on welded joints in intermediate grade billet-steel reinforcing bars to determine an

W. W. SANDERS, Jr. is Assistant Professor of Civil Engineering, University of Illinois; P. G. HOADLEY is Assistant Professor of Civil Engineering, Vanderbilt University; and W. H. MUNSE is Professor of Civil Engineering, University of Illinois.

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Table 1—Chemical and Physical Properties of Reinforcing Bars

(a) Chemical composition of steel bars

Chemical content, %				
C	Mn	P	S	Si
0.43	0.39	0.019	0.035	0.15

(b) Physical properties of steel bars

Yield strength, psi	Tensile strength, psi	Elongation in 8 in., %
51,800	80,000	21.2

indication of the fatigue behavior of these joints. In this paper, investigations of several joint configurations commonly used in field construction are reported. In addition, the effect of concrete encasement on the fatigue behavior also has been investigated.

Materials and Test Specimens

To reduce the number of variables studied, the reinforcing bars used in this investigation were limited to intermediate grade No. 7 steel bars conforming to ASTM Specification A15-58T. The chemical properties as shown in the mill report and physical properties as obtained from coupon tests are given in Table 1. The coupon tests indicate that the bars actually passed the minimum requirements for hard grade billet-steel reinforcing bars, even though the bars were purchased as intermediate grade bars and the mill report indicated physical properties of this grade. It should be realized, however, that although under the present ASTM specifications considerable variation in both physical and chemical properties may be obtained in any one grade of reinforcing bar, the properties in Table 1 are similar to those likely to be found in materials in the field. Results obtained using these bars are believed indicative of the fatigue behavior which may be expected for many of the billet-steel reinforcing bars.

The cement used in the fabrication of the concrete encasement blocks was high-early strength (Type III) cement. The aggregates were Wabash River sand with a fineness modulus of about 3.0 and Wabash River gravel with a maximum size of 1 in. The concrete mix was 1:2.7:4.2 by weight, with a water cement ratio of from 8 to 9 gal per sack ($w/c \cong 0.75$), depending on the moisture content of the aggregates. This could be expected to give a concrete with a 4000 psi compressive strength at the time of testing.

Details of the welded joints studied in this investigation are shown in Fig. 1. The bars were sawed to the proper joint configuration and then securely clamped to a welding jig so that all welds could be deposited in the flat position. For the double-V butt welds, therefore, it was necessary to rotate the specimen about the horizontal axis at intervals during welding. In the fabrication of the V-shaped butt welds it was necessary to place a number of small weld puddles (approximately 15) because of the joint configuration. However, for the angle-splice welds it was possible to make several small longitudinal weld passes along the length of the $2^1/_4$ in. angle. The welding procedures for these joint configurations are shown in Fig. 2.

It should be noted that after deposition of the first puddle in the double-V butt weld, the bar was rotated 180 deg about a transverse horizontal axis and the root back chipped to expose sound base metal. Two puddles were then deposited before the bar was rotated to its original position, and two additional puddles were deposited. This sequence was followed until the welded joint was completed. In order to improve the weld quality at the ends of the angles in the angle-splices, the fillet welds were deposited in a sequence such that the

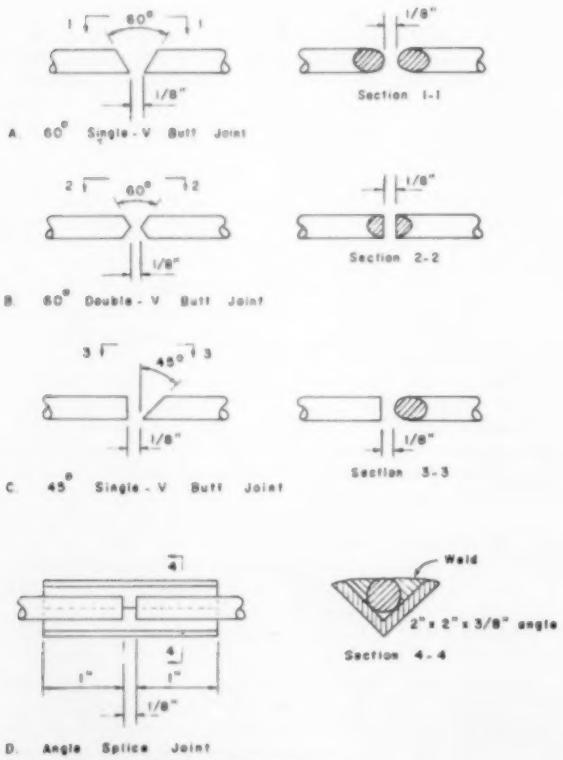


Fig. 1—Details of butt-welded joints

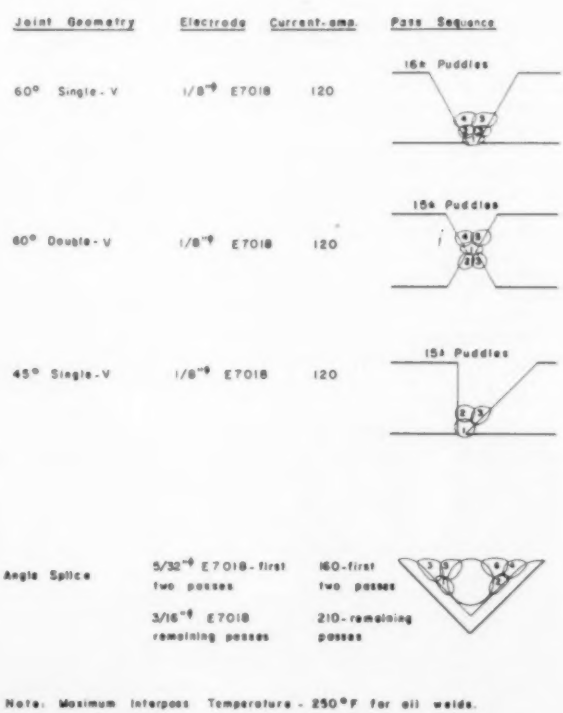
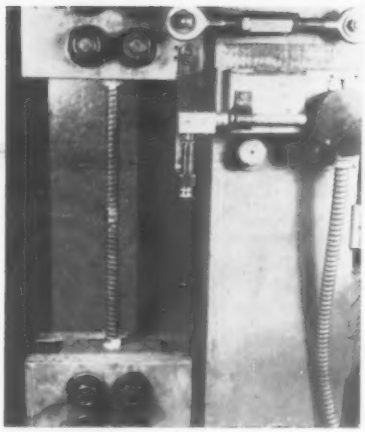
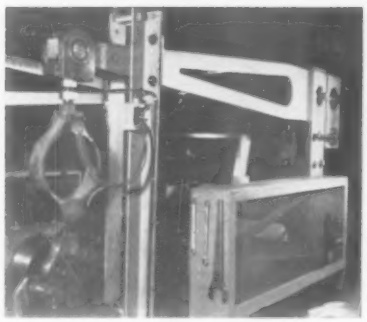


Fig. 2—Welding procedure for reinforcing bars



(a) Test set-up



(b) University of Illinois 50,000 lb fatigue testing machine

Fig. 3—Typical fatigue test set-up

passes alternated between fillets and the successive passes in each fillet were deposited in opposite directions.

No preheat or postheat was applied because previous tests[2] on welded reinforcing bars of similar chemical composition indicated little advantage, if any, to heat treating the bars. The welding procedure used in this investigation did qualify according to a standard welding procedure qualification test,[3] but this only indicates that the procedure is satisfactory for static loadings. All welds, including the qualification specimens, were X-rayed before testing to evaluate porosity distribution and to permit a correlation of crack locations and relative fatigue lives of the specimens with weld defects. A minimum sensitivity of 2% was obtained in the center of all specimens with a penetrometer placed on a $^{7}/_{8}$-in. steel plate (same thickness as nominal thickness of reinforcing bar) adjacent to the welded bar and and not on the specimen, itself.

Although the majority of the tests were conducted on unencased deformed bars as shown in Fig. 3a, a number of specimens were encased in concrete to obtain an indication of the effect of bonding and confinement. The bars were placed in a 6 x 6 x 15 in. concrete block. Some of the encased bars had cracks fabricated in the concrete at the welded joint, prior to testing, to simulate the worst possible cracking condition, i.e., a crack occurring at the welded joint.

Test Procedures

All static tests were conducted in a hydraulically operated 120,000 lb Universal testing machine. The fatigue tests were conducted at room temperature in a 50,000 lb capacity University of Illinois lever-type fatigue testing machine which operates at a speed of approximately 300 cpm. The essential features of the machine are shown in Fig. 3b. A variable throw eccentric, which transmits the force to the specimens through a dynamometer and lever system at a multiplication factor of approximately 10 to 1, is adjusted to give the desired range of load. The mean load is set by means of a turnbuckle mounted above the dynamometer. The load on the specimen is determined from electrical resistance strain gages mounted on the dynamometer.

To hold a specimen in the testing machine, a tapered fitting was cast on each end of the test specimen with a high-strength tin-base babbitt. The specimen assembly was then bolted into special gripping fixtures in the fatigue machine. This babbitt grip was used in all fatigue tests to reduce to a minimum the critical stress conditions at the grips and to provide an effective transfer of load to the bars. The bars were then loaded statically to the maximum desired stress and this load was held for a short period of time so that plastic flow in the babbitt would reach stable static equilibrium.

The design of the hollow grip used in most of the tests was such that either tensile or compressive loads could be applied to the specimens. In some of the initial fatigue tests, however, it was necessary that the specimen have a tension applied at all times because of the construction of the grip. The design of these grips did not provide for a compressive loading. Accordingly, the stress cycle applied in all of the "zero-to-tension" tests was varied from a low tension of about 2000 psi to a maximum tension.

After the load was stabilized, the fatigue machine was run continuously until specimen failure or until 2,000,000 cycles or more of loading had been applied. During the tests, the load was checked and adjusted as often as necessary to maintain the desired loads. Failure of the specimens is reported as the number of cycles at which the fatigue crack was large enough to allow a sufficient increase in the elongation of the specimen to

Table 2—Results of Fatigue Tests of Unwelded Reinforcing Bars

Specimen	Maximum stress, psi	Cycles to failure	Fatigue strength, psi $f_{100,000}$	Fatigue strength, psi $f_{2,000,000}$
"Zero-to-tension"				
1	38,000	272,900[a]	47,700	...
3	38,400	213,800	45,500	...
4	30,000	581,000	44,200	22,800
5	30,000	501,600	42,800	22,100
6	42,000	242,700	51,100	...
7	28,000	4,208,700[b]	...	28,000
8	29,000	867,400	...	23,100
9	28,000	1,336,500	...	25,700
		Avg.	46,300	24,300
Tension = compression				
10	22,000	225,100	25,200	...
11	22,000	171,900	24,100	...
12	17,000	689,400	23,600	14,200
13	17,000	633,000	23,300	14,100
14	15,000	1,247,500	...	13,900
15	14,000	2,884,300[b]	...	...
16	25,000	46,400[a]	21,900	...
17	14,500	2,940,100	...	14,500
		Avg.	23,600	14,200

[a] Failed in test section away from grips.
[b] No failure.

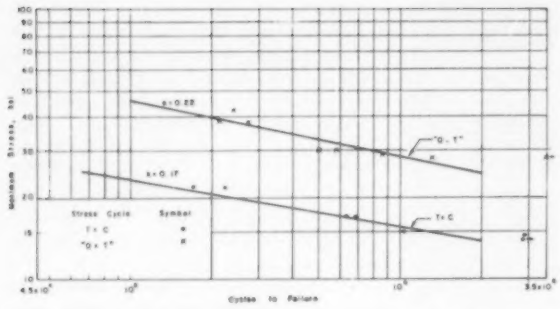


Fig. 4—Results of fatigue tests of unwelded reinforcing bars

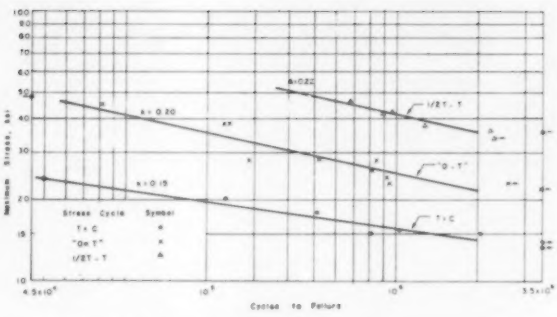


Fig. 5—Results of fatigue tests of 60 deg single-V butt welded reinforcing bars

actuate a microswitch and stop the machine. It was found that the size of crack necessary to actuate the microswitch was of little importance since the number of cycles from a visible crack to complete failure was quite small.

Evaluation of Fatigue Tests

Fatigue strengths corresponding to failure at 100,000 and 2,000,000 cycles have been computed from the equation,[4] $f = S(N/n)^k$, so that the results of the tests under the same type loading cycle but at different stress levels may be compared numerically. In this equation, S is the maximum stress to which the test specimen is subjected, N is the number of cycles to failure, and n is the number of cycles for which the fatigue strength, f, is desired; k is an experimental constant determined from the slope of a straight line drawn through the average results of the fatigue tests plotted on a log-log basis.

In order that the fatigue data will not be extrapolated too far, data from failures only up to 600,000 cycles were used to compute the fatigue strength for 100,000 cycles. If the fatigue life was greater than 300,000 cycles the stress was used to compute the fatigue strength for failure at 2,000,000 cycles. If the failure occurred between 300,000 and 600,000 cycles, both fatigue strengths were computed from the data. For those specimens having a fatigue life greater than 2,000,000 cycles, a value of 2,000,000 has been used for N.

Discussion of Test Results

Tests of 60-Deg Single-V Butt-Welded Joints

Although there were several welded joint configurations used in this study, only the 60 deg single-V butt-welded joints as shown in Fig. 1a were tested statically. The tests of the welded bars indicated a yield strength of 50,700 psi and an ultimate strength of 79,600 psi, while tests of the unwelded parent material showed an average yield strength of 51,800 psi and an average ultimate strength of 80,000 psi. Nearly 100% joint efficiency was obtained under static conditions. Results of similar tests reported previously by two of the authors[1,2] indicated that, if the ultimate strength of the electrode is equal to that of the parent material, joint efficiencies higher than 90% may be expected from most butt-welded joints in rein-

Table 3—Results of Fatigue Tests of 60 Deg Single-V Butt Welded Reinforcing Bars

Specimen	Maximum stress, psi	Cycles to failure		Fatigue strength, psi $f_{100,000}$	$f_{2,000,000}$
"Zero-to-tension"					
W-1	38,000	242,100		45,300	...
W-2	28,000	287,100		34,600	...
W-3	28,000	522,400		39,000	21,400
W-4	28,000	853,100		...	23,600
W-5	38,000	232,800		45,000	...
W-6	26,000	823,600		...	21,800
W-7	24,000	944,400		...	20,700
W-8	22,000	4,937,400[a]		...	22,000
W-9	23,000	2,660,000[a]		...	23,000
W-10	23,000	950,500		...	19,800
W-11	48,000	38,500		39,700	...
W-54A	45,000	81,800		43,200	...
			Avg.	41,100	21,800
Tension = compression					
W-12	15,000	2,095,600		...	15,000
W-13	18,000	510,000		23,000	14,600
W-14	15,000	815,400		...	13,100
W-15	13,500	4,300,000[a]		...	...
W-18	20,000	234,500		22,700	...
W-19	14,000	3,734,000[a]		...	14,000
W-20	15,500	1,040,000		...	14,000
W-21	24,000	50,000		21,600	...
			Avg.	22,400	14,100
1/2 Tension-to-tension					
W-16	42,000	970,000		...	35,900
W-17	42,000	900,500		...	35,300
W-42A	38,000	1,287,400		...	34,500
W-44A	36,000	4,147,700[a]		...	36,000
W-45	34,000	2,327,700[a]		...	...
W-52	36,000	2,239,900		...	36,000
W-53	46,000	683,000		(70,000)	36,300
			Avg.	(70,000)	35,500

[a] No failure.

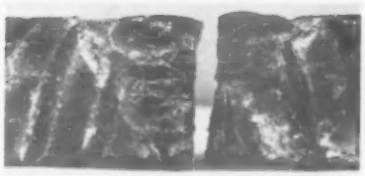
forcing bars.

The results of the fatigue tests of unwelded reinforcing bars are presented in Table 2 and Fig. 4. Although babbitt grips were used to reduce the stress concentration where the bars entered the pull-head assembly, there was still a slight increase in stress at this point. Because of this stress concentration effect, failure of the bars generally occurred at the end of the babbitt grip. However, this stress concentration effect is actually very small since several of the specimens failed in the unrestrained area away from the grip. It is believed, therefore, that the fatigue strengths obtained from these unwelded specimens indicate the actual behavior of the bars.

Table 3 presents the results of fatigue tests on 60 deg single-V butt-welded joints. These results are shown graphically in Fig. 5 All of the fatigue specimens were tested in the as-welded conditions. An examination of the fracture surfaces, fracture locations and the X-ray negatives indicated no apparent correlation between weld defects and the fatigue behavior. Nearly all specimens had a concentration of gas porosity in the root area. However, the fatigue failures seemed to occur at random with the majority of the failures initiating at the toe of the weld although a number of specimens did fail directly through the root.

A typical fracture surface and fracture location of a butt-welded joint are shown in Fig. 6. In several instances, however, fatigue cracks developed along the edge of the weld reinforcement simultaneously with a failure through the defective weld root and make it appear that no significant increase in fatigue strength would accompany the elimination of the internal defects, unless such procedures also improved the geometry and the fatigue resistance at the edge of the weld.

Referring to Tables 2 and 3, a comparison of the fatigue strengths of the unwelded reinforcing bars and the reinforcing bars with 60 deg single-V butt-welded joints show only a slight reduction in fatigue strength due to the welded connection. Reductions in fatigue strengths resulting from the welded joints at lives of 100,000 and 2,000,000 cycles were approximately 13 and 10% respectively for a "zero-to-tension" stress cycle. For complete reversal tests, the reductions in fatigue strength, due to the butt-welded joints, were 5% at 100,000 cycles and about 1% at



(a) Fracture location

(b) Fracture surface

Fig. 6—Typical failures of 60 deg single-V butt-welded joints

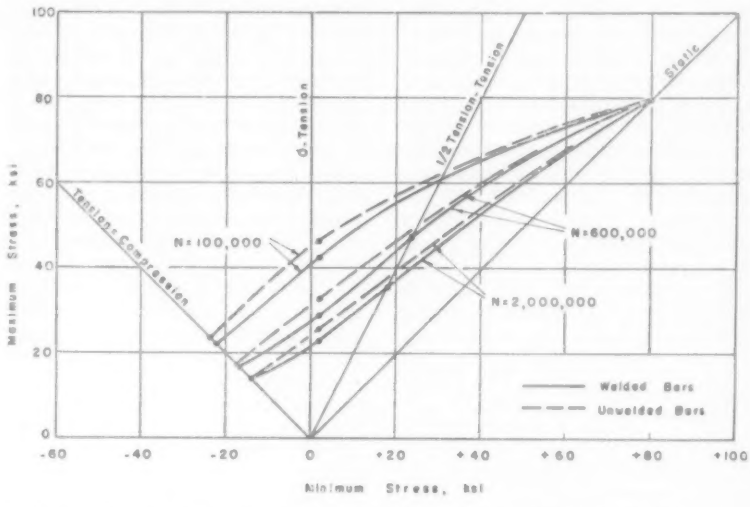


Fig. 7—Modified Goodman diagram for 60 deg single-V butt-welded reinforcing bars

2,000,000 cycles. Results of previous fatigue tests[4] on plain plate specimens and transverse butt-welded joints in A242 steel (a steel with similar physical properties) indicate that reductions of at least 30% can be expected in the fatigue strengths of plain flat plate material due to the addition of a transverse butt-welded joint. The small reduction in fatigue strength of the welded bar is due primarily to the fact that the stress concentration at the weld is only slightly greater than at the deformations. The deformations, because of their shape, actually reduce considerably the fatigue strength of the parent material. The stresses reported in this paper are the nomial stresses in the reinforcing bars. No attempt has been made to obtain the fatigue strength of plain bars or the stress concentration effect of the deformations.

In addition to the tests of welded bars under cycles of "zero-to-tension" and full reversal, seven welded reinforcing bars were tested under half tension-to-tension. However, the capacity of the testing machines limited the latter tests to studies of welded reinforcing bars with lives above 600,000 cycles. An indication of the relationship between the fatigue strengths of welded and unwelded bars can be seen in the modified diagram of Fig. 7.

Tests of Other Butt-Welded Joint Configurations

All of the previous discussion of welded joints in reinforcing bars has dealt with results of tests on 60 deg single-V butt-welded joints. However, to obtain a more complete picture of the fatigue behavior of welded reinforcing bars, tests were conducted also on several other joint configurations—Figs. 1b, 1c and 1d. To indicate the relationship between the behavior of each of these joint types under cyclic loading, several specimens of each joint configuration were tested under the same "zero-to-tension" stress cycle. A stress cycle of 2000 to 28,000 psi was selected so that all of the specimens to be tested would fail within 2,000,000 cycles. The results of these tests are shown graphically in Fig. 8. Although only the average of the results for each joint type is shown, individual tests generally varied little from these values.

The results of the tests on angle-splice welded joints indicate the effect of the severe stress concentrations at the ends of the angle and at the point where the bars butt together. If one assumes that the

slope of the S N diagram for the angle-splice joint is the same as that of the 60 deg single-V butt-welded joints (Fig. 5), the fatigue limit for the angle-splice joint is found to be only about 17,000 psi or 70% of that of the 60 deg single-V butt-welded joint. Since the slope is very likely greater than that for the single-V joint, the fatigue limit is probably less than 17,000 psi.

Each 45 deg single-V butt-welded joint failed along the vertical interface because of a lack of penetration of the weld which caused a short fatigue life for these joints. The fatigue life of this joint corresponds to a fatigue limit of about 19,000 psi. Difficulty is encountered in eliminating this lack of penetration because the configuration of the joint causes unequal heat build-up along the interfaces. The lower life of the double-V butt-welded joint compared to that of the single-V butt-welded joint can probably be attributed to a partially additive stress concentration effect at the edges of the weld reinforcement which, for this joint, are diametrically opposite each other. In the 60 deg single-V butt-welded joints, however, the edges of the reinforcement at the root and face are offset.

Effect of Concrete Encasement on Fatigue Behavior

In order to obtain an indication of the fatigue behavior of the welded reinforcing bars in a reinforced concrete beam, a few specimens were encased in concrete prior to testing. In Fig. 8 the effect of the concrete block encasement on the fatigue behavior of 60 deg single-V butt-welded reinforcing bars is shown graphically. One series of tests was conducted on welded bars encased in 6-x 6-x 15-in. concrete blocks with a thin cardboard sheet placed at the center of the welded joint to ensure the development of a crack at that location. A second series was similar in construction to the first series except that the cardboard sheet was not used and the cracks were allowed to develop at random during the testing. In the second series of tests, none of the specimens developed a crack within 3 in. of the weld, thus allowing the concrete to pick up some of the load from the deformed bar and transmit it across the critical weld section. Also, a lowering of the actual mean stress in the bar may have been caused by shrinkage forces in the concrete block. These forces develop in the bar during curing and may be as high as 3000 to 4000 psi. Thus, it is possible, based on a comparison with the fatigue behavior of the unencased welded bars and taking into account the above indications, that the actual maximum nominal stress in the bar at the welded joint may have been as low as 22,000 psi, compared to the reported 28,000 psi. The reduction in the actual stresses would give the longer life for the encased welded bar.

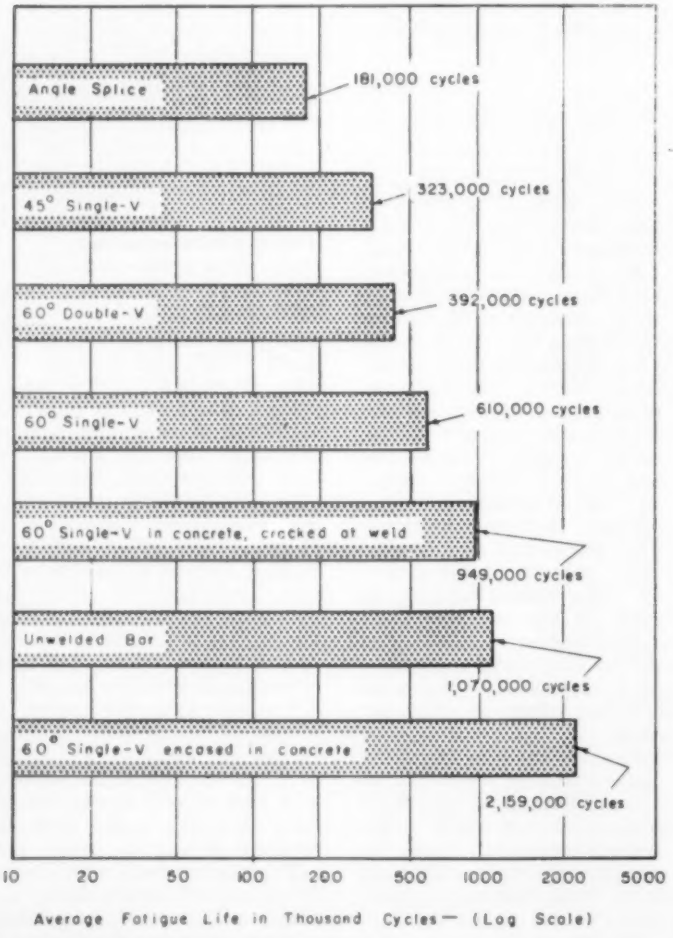


Fig. 8—Average fatigue life for various welded joints on a stress cycle of 2 to 28 ksi

Although it seems that the average life of the welded bar encased in a concrete block with a crack fabricated in the concrete at the welded joint should be approximately the same as a similar unencased welded bar, the encasement actually increased the average life over 300,000 cycles at 2000 to 28,000 psi; this is equivalent to an increase in the fatigue limit of approximately 13%. This increase in life can probably be attributed in part to the cement mortar in the concrete which filled up the irregularities at the weld reinforcement and yielded a smoother and more uniform transition from the parent metal to the weld reinforcement.

Gilde[6] has shown that by using a plastic type coating (epoxy resin) over 60 deg single-V transverse butt-welded joints, it is possible to increase the fatigue strength of these joints considerably. By spreading the light plastic coating over the heat-affected zone and the weld bead, Gilde found it possible to increase the fatigue strength at 2,000,000 cycles by almost 100%. Although there is only a slight similarity between the tests of the concrete-encased welded reinforcing bars reported in this paper and the plastic-coated butt welded joints, the comparison does give some further foundation to the previous indication of the beneficial effect of the cement mortar.

Although not reported individually in this paper, several fatigue tests of concrete encased

lap-welded joints in reinforcing bars were conducted in this investigation. However, even with concrete blocks to restrain the bending in the specimens, failure occurred in a very small number of cycles. The eccentric loading was sufficient in these cases to cause severe cracking of the encasement blocks. Consequently, the data were not considered representative of what might happen in a reinforced concrete member with lap-welded joints and have not been included in the comparisons of this paper. Fatigue lives of only about 40,000 cycles were obtained for a stress cycle of 2000 to 28,000 psi. These few tests indicate that fatigue tests of actual reinforced concrete beams with lap-welded reinforcement will be required to obtain a true indication of the fatigue behavior of the encased lap-welded joints.

The fatigue behavior of the lap-welded reinforcing bars in reinforced concrete beams cannot be obtained from the tests of axially loaded welded joints. By the same token, the concrete encasement of butt-welded reinforcing bars gives an increase in the fatigue strength, also indicating a need for study of the behavior of these joints in actual reinforced concrete beams before any design recommendations are formulated. At present, an investigation is underway to determine the fatigue behavior of reinforced concrete beams with welded reinforcement so that a better understanding of the behavior of the actual beam and a correlation between this behavior and that of the axially loaded welded reinforcing bars may be obtained.

Conclusion

1. Joint efficiencies between 90 and 100% can generally be expected for butt-welded joints in reinforcing bars if the ultimate strength of the electrode is equal to that of the parent material.

2. For the intermediate grade reinforcing bars tested, the average fatigue strength of the 60 deg single-V butt-welded joints was only about 10% lower than that of the unwelded bar for a stress cycle of "zero-to-tension," and about 5% lower for a stress cycle of complete reversal.

3. The 60 deg single-V butt-welded joint provided the highest fatigue strength of any of the butt-welded joints tested. The 60 deg double-V and 45 deg single-V butt-welded joints exhibited fatigue strengths about 15% lower than the 60 deg single-V butt-welded joint, while the angle-splice welded joint gave a fatigue strength about 30% lower.

4. Concrete encasement of the butt-welded joints caused an increase in the fatigue strength of about 15%. However, this increase may be higher or lower depending upon the location of the cracks in the concrete.

Acknowledgments

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The authors acknowledge the help of H. Abe, Research Assistant in Civil Engineering, who conducted some of the early tests in this investigation. The Welded Highway Structures Advisory Committee of the Illinois Cooperative Highway Research Program have acted in an advisory capacity in the planning of this program. However, the opinions expressed in this paper are those of the authors and do not necessarily represent those of the committee or the sponsoring agencies.

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Authors....

please note!

All authors interested in presenting papers at the 1962 AWS National Fall Meeting to be held in Milwaukee, Wisconsin on October 1–4, are advised that the usual forms, "An Invitation to Authors" and "Author's Application Form," were printed as a detachable insert in the October issue of the Welding Journal.

Additional copies of the forms may be obtained by writing to AWS Headquarters, 345 East 47th Street, New York 17, New York.

Considerations on the Use of Gas Mixtures in Shielded Arc Welding with Consumable Electrodes

The gas mixture proving most suitable for the welding of mild steel consists of 80% argon, 15% carbon dioxide and 5% oxygen

BY L. WOLFF AND M. KOMERS

The protective gases used today for shielded arc welding may be subdivided into three different groups, varying according to their chemical properties: inert gases, reducing gases and oxidizing protective gases. Table 1 gives a survey of gases and mixtures as used at present and their respective applications.

Shielding Gas Characteristics

Inert Gases

Of the inert gases, practically only argon and helium are of any importance for welding technique. Of the two, argon is predominant because helium can only be applied as a welding gas in such places where it is produced as a natural gas, e.g., in the U. S. Under the protection of inert gases all metals are weldable, except for the unalloyed and low alloy steels when utilizing the gas metal-arc process. The difficulties that arise during the processing of steels are of a physical nature; they are described elsewhere in this paper.

Reducing Gases

The reducing inert gases contain hydrogen as a chemically efficient component. Pure hydrogen, however, is not suitable for welding with a direct electric arc between an electrode and the workpiece. Given a suitable arc length, the arc would have too high an arc voltage to be safely operated with sources of current of conventional design. Moreover, especially in the case of metal arc welding, atomic hydrogen would come into contact with the welding drops which are transferred by the arc core. In part this contact would also become active with the welding melt, which would result in heavy hydrogen absorption as well as bath agitation and formation of pores as the welding puddle solidified. Therefore, pure hydrogen can only be used in an electric arc separated from the work piece as is the case in atomic hydrogen arc welding. Obviously the dissociated hydrogen does not come into direct contact either with the filler metal or the molten bath, as it cools already previously below its recombination temperature. For this reason, the atomic hydrogen welding process can be applied for all weldable metals and alloys without producing hydrogen embrittlement. For physical reasons as well as for reasons of safety, the hydrogen content in case of the direct arc is generally kept below 40%. The real hydrogen contents of welding gases (consisting in their basic composition of argon) are being rated in accordance with the process and the material in question.

Whereas the hydrogen-argon mixtures are used in order to accelerate the welding of aluminum and steel, the reducing effect of these mixtures is used deliberately in nickel processing in order to counteract CO porosity. The danger of such porosity results from the presence of carbon in the nickel in that the carbon reacts with oxygen-traces in the inert gas and the oxide slags, thus forming CO. For nickel, the hydrogen content of the mixtures must be kept below 6.5% because essentially higher contents would lead to the formation of hydrogen pores.

For the gas metal-arc welding of steel, hydrogen contents of 0.5% are already sufficient to effect an agitated bath as well as heavily porous seams. In the case of aluminum, the limit is around 8%. In gas tungsten-arc welding used for the working of aluminum as well as stainless steels, mixtures containing 15% hydrogen have been particularly successful. Aluminum can still be welded up to 30% hydrogen. However, the resulting electric arcs are inconvenient for practical handling purposes.

The application of reducing gases as a back-up is gaining an ever wider importance. Here, above all, use is made of the nitrogen-hydrogen-mixtures in Germany known as "Formiergas" for the welding of tubes. The application is not, however, restricted only to shielded arc welding; it is also used to great advantage in connection with gas welding, particularly in respect to circular tubing seams. Also the tests conducted in order to protect resurfacing deposits from scaling during cooling stage have proved successful. Apart from this, it should be noted that N_2-H_2 mixtures used for argon-shielded arc cutting have presented novel possibilities in unalloyed and low alloy steels.

Oxidizing Gases

When subjecting steel to gas metal-arc welding which is only possible with super-deoxidized wires, viscous weld metal with elevated surface tension was obtained in pure argon. The problems are to fill the groove, to avoid undercutting and to prevent gas entrapment in the weld deposit. It was only after oxygen had been added to the argon that a correct flow of the welding wire to the work was obtained with sound wetting of the weld groove and that no-porosity could be secured. In the case of unalloyed, soft filler metals having a degree of deoxidation by silicon three times the normal value, about 3% O_2 must be added to the argon in order to obtain favorable welding conditions. For wires with five- to sevenfold super-deoxidation by silicon, titanium and aluminum

L. WOLFF is with Linde's Eismaschinen AG, Hollriegelskreuth bei Munchen, West Germany and M. KOMERS is with Phoenix-Rheinrohr AG, Dusseldorf, West Germany.

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5% of oxygen are needed to maintain porosity-free welds.

Iron is very slightly oxidized by the oxygen. As long as there is sufficient silicon, manganese and carbon in the steel, it becomes possible to weld steels in heavily oxidizing gases without impairing quality. Here it should be kept in mind that, during the welding of any metal, there is only a very short reaction time. It is essential for the welding of steels that the arc be shielded from atmospheric nitrogen. If this is not done, the nitrogen unites with the products of the welding zone, thus leading to the formation of pores and cracks and—in particular—to embrittlement.

Welding with CO_2 must, therefore, in no way affect the quality. Well-known investigations of the Japanese on $CO_2 + O_2$ mixtures have even shown that certain advantages may still be derived from stronger oxidizing protective gases, such as additions of O_2 up to 27.5%, than CO_2. However, during comparative investigations of welds made on the one hand in inert gas and on the other hand in CO_2, differences in quality have been revealed. They indicate that, in spite of the short reaction times and the protection afforded by oxidizing agents, intensive oxidation makes its influence felt by a marked decrease in quality. In particular it should be noted that, in the case of these gases, hydrogen quantities of only 0.05 ml/g lead to formation of apophyllite.

Table 1—Gases and Gas Mixtures for Cutting and Welding Arcs

Shielding gases	Chemical behavior	Gas metal-arc welding	Gas tungsten-arc welding
Ar	Inert	All metals except for steel	All metals
Ar + He	Inert	Al- and Cu-alloys to avoid porosity	Copper on account of greater energy
He	Inert	Used only in USA	.....
Ar + Cl (traces)	Inert	Al-alloys to avoid porosity	.....
H_2	Reducing	Only plasma heat utilizable	(Arcatom)
Ar + 20 ÷ 50% H_2	Reducing	.....	Plasma ray cutting of Al, Cu, Mg, a.o.
Ar + 15% H_2	Reducing	.....	Welding of stainless steels, acceleration of welding speed
Ar + 6% H_2	Reducing	.....	Welding of nickel and nickel alloys (control and combating of pores)
N_2 + 10 ÷ 40% H_2	Reducing	.....	Plasma-cutting of carbon- and stainless steels
N_2	Reducing	On Cu stronger arc	Plasma-cutting of stainless steels
Ar + 1% O_2	Oxidizing	Alloy steels	.....
Ar + 3% O_2	Oxidizing	Low carbon steels, with deoxidized wire (Fe 32)	.....
Ar + 5% O_2	Oxidizing	Steel, with super-deoxidized wires (Fe 55, Fe 67)	.....
Ar + 5 ÷ 10% CO_2	Oxidizing	Steel, super-deoxidized wires necessary	.....
Ar + 25% CO_2	Oxidizing	Short-arc, CO_2-character	.....
Ar + 5% O_2 + 15% CO_2	Oxidizing	Universal protective gas (Coxogen) for steel, multi-layer welds, position welds, short-arc, non-poisonous waste gases	.....
CO_2	Oxidizing	Multi-layer welds on killed steels, single-layer welding, machine welding	.....
CO_2 + 3 ÷ 10% O_2	Oxidizing	CO_2-character, lower sensitivity to crack formation, also for low alloy steels	.....

Special Gases

Great metallurgical importance may be ascribed to the successes obtained by the argon mixtures with volatile chlorine, fluorine and iodine compounds used for combating porosity in aluminum welds. However, research work undertaken in this field has not yet been completed, and the effects of these gas mixtures are not exclusively metallurgical in nature.

Furthermore, mention should be made of nitrogen which is predominantly used today as an electric arc gas for the cutting of alloyed steels. Its tendency to react with quite a number of metals and to form undesired nitrites accounts for the fact that in the majority of cases it cannot be used as a welding gas. Only for the welding of copper, substantial results could be achieved by applying both the tungsten arc and the metal arc processes.

In order to effect carburization of the weld deposit, tests have been conducted with portions of hydrocarbon added to argon and to inert gas mixtures. Table 2 gives the test results obtained with acetylene.

Physical Meaning of Electric Arc Welding Gases

Based on experience obtained from electric arc and inert gases, it is possible to say that the physical changes of the electric arc properties brought about by the inert gas and the electric arc atmosphere

Table 2—Carburization of Weld Deposit

Additional (%) of C_2H_2 contained in 20 l./min	Variation of C-contents (%) when using Argon	95% Argon +5% O_2	80% Argon +15% CO_2 +5% O_2	Acetylene, %
0	0.11	0.04	0.07	0
0.7	0.16	0.05	0.08	3.5
1.0	0.18	...	...	5.0
1.2	...	0.10	0.09	6.0
1.5	0.27	...	...	7.5
1.6	...	0.16	0.11	8.0
1.8	0.35	...	...	9.0
2.0	...	0.22	0.15	10.0

NOTES: 1. Metal arc deposition by means of welding rod Fe 67, diameter 1.6 mm, welding current 290 A, arc voltage 28 V, total quantity of inert gas 20 l/min.

2. The tests which have had a thoroughly positive result show that here ample opportunities suggest themselves for further research on an essential field of electrical arc welding.

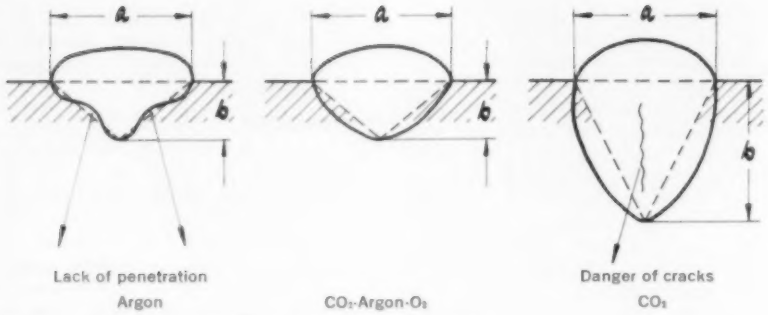

Fig. 1—Shapes of penetration for different inert gases

produced by the latter may be of considerably greater influence on the weld than the chemical-metallurgical behavior between inert gas and melt. As a classical example, one need only to mention the purifying effect of the arc on the surface of metals forming high-melting oxides (in the case of alternating and direct current welding with the electrode at the anode).

Although both argon and helium are inert, the purifying effect of argon is by far superior to that of helium. Today it is known that this difference in the effect of the two electric arcs is mainly due to the difference in the thermal conductivity values of both gases. In the case of helium, thermal conductivity is high (0.123 kcal/m.h.° C). The arc plasma that receives its conductivity by way of thermal ionization will therefore expand in the case of helium, thereby reducing the current density on the face of the material. Simultaneously, however, the voltage gradient of the arc length is increased by the discharge of heat from the electric arc core; this in turn, means an increase of energy consumption in the electric arc. The helium arc acts, therefore, vigorously and on a broad area. In the case of argon possessing a much lower thermal conductivity (0.014 kcal/m.h.° C), the plasma stream in the electric arc core produced by the flow of current remains closed. This means an increase of temperature and current density on the piece to be welded. The voltage gradient of the arc length becomes relatively low.

Given equal arc lengths, the argon arc has less energy than the helium arc. It produces, however, very high local temperatures and promotes the loosening of the high-melting oxides and, therefore, also purification. But the concentration of the electric-arc energy in the arc centerline produces also the trend toward the formation of extremely deep penetrations in the shape of the plasma stream. This might very easily lead to an agitated bath with the resulting formation of blowholes. In this connection it should be noted that the gas metal-arc welding of aluminum in argon has proven very susceptible to pore formation; by additions of helium to argon, the susceptibility to pores is considerably reduced. Here too, a purely physical alteration has occurred in which the concentrated electric arc core of the argon is extended by means of the improved conductivity through helium. Application of this knowledge should be extended to all arc welding processes.

The best welds were obtained if the arc, positioned broadly on the base, remains included within the molten pool formed under the arc.

A considerable part of difficulties arising in the welding of steels by means of an inert-gas-shielded arc and carbonic acid is caused by an unfavorable physical behavior of the arcs due to the arc gases. The argon arc, for instance, has a very hot core whose radiation produces a second arc enveloping the core. As both develop penetration, the covering arc penetrates only at a very flat angle, due to its low current density, meaning that the penetration proper of the core is covered. This will inevitably result in certain difficulties for the welder regarding proper control of the weld puddle, particularly at the base of single V grooves and at butt joints.

The carbon-dioxide arc, on the other hand, is sufficiently wide, because dissociation and recombination processes expand the heat of the arc core in a similar way. On the other hand, the wire in the carbon-dioxide arc melts only in irregular droplets. This results in heavy spatter losses, together with the other properties of the arc, unless the arc is kept at a very short distance. This short arc, again, reveals a marked tendency to undercut.

Considering the importance of steel welding, tests have been carried out with a view to obtaining a suitable plasma form. The gas mixture found to be particularly adapted for this purpose contains about 80% argon, 15% carbon dioxide, and 5% oxygen—Fig. 1. This gas mixture may be regarded as a special gas for the welding of steel, since it combines the favorable welding features of the gases argon and carbon dioxide whereas each of these gases for itself has an unfavorable effect.

Summary

In a metallurgical sense for welding, inert, reducing and oxidizing protecting gases are used.

Of the different inert gases only argon and helium and mixtures of both can be applied—with gas tungsten-arc for all metals and with gas metal-arc for all metals except steels.

Shielding gases of reducing character are pure hydrogen (arc-atom) and mixtures of argon with hydrogen. The gas tungsten-arc process allows the use of higher percentages of H_2 in argon than gas metal-arc welding.

The gas metal-arc welding of steels is mostly done under oxidizing gas protections: argon-O_2, argon-CO_2, argon-CO_2-O_2, CO_2-O_2 mixtures and Co_2.

Furthermore, there are argon-halogen mixtures for combating porosity, N_2 and N_2-H_2 mixtures for plasma cutting and gas mixtures with contents of hydroxides of carbon for carborization of the welding melt.

Still more important than the metallurgical effect of the protecting gas is the influence on the physical character of the arc. The cleaning effect of argon is much more pronounced than that of helium with gas metal-arc welding, helium and argon mixtures give a more favorable penetration. For steel gas metal-arc welding neither the character of the argon-arc nor that of the CO_2 arc are satisfactory. Here a special gas-mixture had to be found, composed of about 80% A, 15% CO_2 and 5% O_2, to eliminate the difficulties of welding.

The *argon arc* has no visible penetration for the welder because, apart from the penetration proper of the argon arc, an additional broad area is caused by a radiation arc of a lower current. Faulty guidance on the part of the welder may, therefore, easily lead to bonding defects.

The *carbon-dioxide arc* has a sound penetration. It operates, however, too deeply and produces a bad ratio between depth and width

of penetration so that there is a permanent danger of cracks. Moreover, heavy oxidation at the edges of the welds prevents broad flowing of the weld.

The *Coxogen-penetration* combines the advantages of carbon-dioxide penetration with those of the argon. The penetration is broad in the root face and reveals sharp contours at the sides. Simultaneously the width corresponds to that of argon so that a favorable ratio between depth and width of penetration is obtained. A further advantage of the Coxogen arc is that it can be kept free of spatter.

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EUROPEAN WELDING RESEARCH

By Gerard E. Claussen

USSR

Svarachnoe Proizvodstvo for March 1961 contains the following articles:

• Submerged-arc flux for welding nickel alloys containing 20 Cr, up to 8 W contained 3 to 5% NaF + SrF_2 to improve the transfer efficiency of Al and Ti. In this way hot cracking was prevented.

• Calculation of pressure of dissolved hydrogen in aluminum weld metal required to form a bubble showed that the metal must contain at least 0.69 cm^3/100 g. for hydrogen to cause porosity. The value 0.69 is the solubility of hydrogen in molten aluminum at the melting point under one atmosphere of hydrogen.

• Porosity in steel welds is ascribed to the oxidation of carbon during solidification when the metal is shrinking.

• A test specimen for determining the maximum and minimum temperatures for brazing consists of a small sheet of the metal to be investigated $1^3/_{16}$ in. square centered on a large sheet 2-in. square. The clearance between the two sheets is 0.002-0.004 in. and a piece of brazing wire is placed against one edge. The minimum brazing temperature is that at which capillary flow is complete at all edges. The maximum is that at which the brazing alloy spreads beyond the small sheet and erodes the base metal. A brazing alloy of Ni-B-Si-Cr composition worked well at 2100° F in soldering a nickel alloy containing 20% Cr in a vacuum. A temperature of 932° F provided good spreading without excessive erosion in brazing aluminum with Zn-5% Al alloy.

• The softening of five types of copper-base spot welding electrodes was confined to the central area of the face and to a depth of 0.05 in. Softening was accompanied by recrystallization. The hardest electrode, 170 Vickers, contained 0.67 Cr, 0.14 Al, 0.22 Mg.

• For depositing a layer of weld metal over an area having an irregular shape, a patented electrode made of sheet metal is used. The electrode is conical with the point resting on the surface of the base metal. The hollow conical electrode is deposited under submerged arc flux. Amperage increases from 500 to 4000 during the six minutes required to deposit a typical cone.

• The assembly of 60 and 100 ton railway freight cars by spot welding is described.

• A new electrode was developed for welding steel containing 0.08 C, 0.2 Si, 16 Cr, 25 Ni, 6 Mo, 0.8 V, 0.14 N. The weld metal had the same composition, except 1.2 V and no nitrogen.

• A photoelectric seam follower for automatic welding is described.

• An extruded covered electrode for welding aluminum deposits weld metal containing 0.23 Fe, 0.53 Si, 0.21 Ti, trace Cu. The hydrogen content of the weld was 3.3 cm^3/100 g. Silumin automobile parts were welded with a similar extruded electrode containing 5% Si.

WEST GERMANY

The West German *Schweissen und Schneiden* contained the following research articles in its August 1960 issue:

• CO_2 welding with a folded, covered electrode is used for structural welding, steel casting repair and the welding of horizontal seams of oil storage tanks. There are six electrode compositions, and a dead wire may be fed into the arc to increase the rate of deposition.

• Impurities in CO_2 for welding were found to increase the porosity and lower the bend-ductility of automatic welds made in rimmed steel with $^3/_{32}$ in. electrode containing 0.18 C, 1.05 Si, 1.30 Mn. A CO_2 purity of 99.85% was required for good results. More than 0.1% air or a total of 0.05% oxygen, hydrogen and nitrogen caused porosity.

• An extensive research was made on the composition and the mechanical properties of electroslag welds in four steels: killed and semi-killed, mild steel, low-alloy steel (0.19 C, 1.38 Mn and 0.58 Si), 0.30% Ce steel, and 0.7 Cr, 0.5 Mo piping steel. The properties of the first two steels were as good in the weld as in the plate. After artificial aging (10% strain, then $^1/_2$ hr at 480°F) the toughness of both plate and weld was low. Hot cracks were observed in the 0.30 C steel, 4-in. thick, but not in 2-in. plates. Normalizing was required to develop the best properties in the Cr-Mo steel.

DR. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

The Hydraulic Bulge Test for Welded Aluminum Sheet

Bulge test proves better than cross-weld tensile test for evaluating performance of high-strength heat treatable alloys in welded structures

BY I. B. ROBINSON, F. R. COLLINS AND J. D. DOWD

ABSTRACT. The hydraulic bulge test is a fast, inexpensive means of predicting the structural performance of welds in high-strength heat-treatable aluminum alloys. Cross-weld tensile data are not sensitive to small changes in welding technique for aluminum alloys such as 2014 and 7075. Thus the bulge test is superior to the cross-weld tensile test for evaluating the performance of these alloys in welded structures such as pressure vessels.

The tester consists of a circular open die into which the panel is bulged, a fixture for clamping the panel against the die so that it will not slip during bulging, a hydraulic system for applying pressure to the panel during bulging, and instrumentation for measuring pressure and bulge height during testing.

Biaxial tensile stress is calculated from values of pressure and bulge height measured during the test. Elongation is determined from the bulge height. The bulge strength and elongation at fracture provide sensitive comparisons among alloys and welding techniques. Visual examination of the fractured panels gives additional valuable information on the relative strengths and ductilities of the weld and parent metal.

Introduction

Experience has shown that uniaxial tensile tests of small cross-weld specimens in high-strength heat-treatable aluminum alloys do not correlate well with the performance of welded structures under service conditions. Correlation is good using simulated structures, but fabricating and testing such structures require a prohibitive expehditure of time and money. Bulge tests have been more or less successful; however, previous procedures were cumbersome and often yielded only qualitative comparisons among tests. This paper presents refinements of equipment and techniques developed for rapid, quantitative bulge testing of welded aluminum sheet.

I. B. ROBINSON, F. R. COLLINS and J. D. DOWD are with the Research Laboratories of the Aluminum Company of America, New Kensington, Pa.

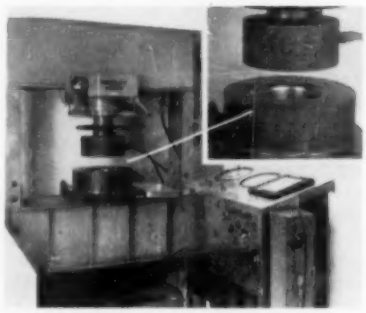


Fig. 1—Bulge tester

Equipment and Test Procedure

A hydraulic bulge tester consists of a circular open die into which the panel is bulged, a fixture for clamping the panel against the die so that it will not slip during bulging, a hydraulic system for applying pressure to the panel during bulging, and instrumentation for measuring pressure and bulge height during testing. A photograph and schematic sketch of the equipment are shown in Figs. 1 and 2. This equipment differs from previous equipment in that clamping is provided by a hydraulic cylinder instead of a large number of bolts that must be tightened before each test and removed after each test. The only specimen preparation required is the removal of the weld bead in the clamped area; this can be done conveniently with an air-driven weld shaver.

In operation, the test panel is centered on the die and clamped against it by a 150-ton hydraulic arbor press acting on a pressure pad. Hydraulic pressure is introduced between the sheet and pressure pad through a duct in the pad. The rate of pressure increase is controlled by a throttling valve in a pressure

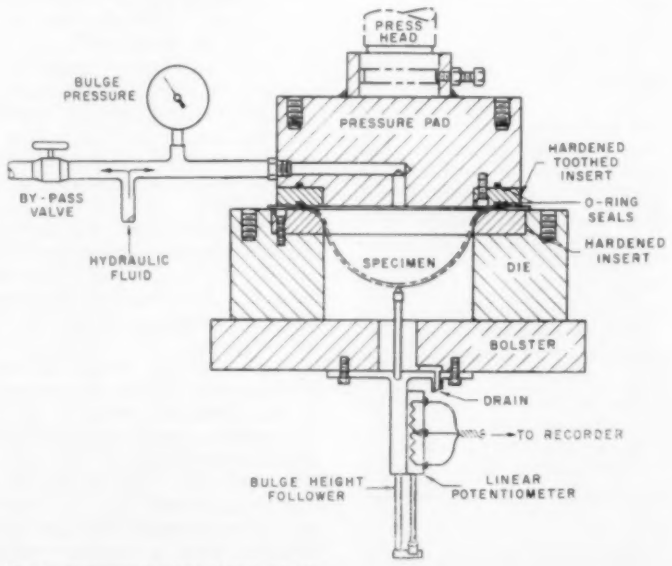


Fig. 2—Schematic view of bulge tester

relief line. Leakage of hydraulic fluid is prevented by a rubber O-ring seated in the pad just within the inner tooth radius. To prevent slippage of the sheet, its periphery is gripped by several concentric circles of sharp teeth machined into a hardened steel insert in the pressure pad. Excessive wear of the lower die is prevented by using a hardened steel insert for the 1-in. relief radius.

The design of the bulge tester is such that the sheet is bulged downward into a die which confines any high pressure spray or flying pieces. The closed lower die also permits the hydraulic fluid to be conveniently drained back into the sump tank of the pump. Water soluble oil is used for ease in cleaning specimens. The same hydraulic pump is used for clamping and bulging by providing suitable plumbing.

A bulge height follower, linked through a magnetic release to a linear potentiometer, rests on the center of the specimen during bulging. Bulge height is recorded continuously during the test. At fracture, the magnetic release breaks, protecting the potentiometer. Bulge pressure is read from gages in the hydraulic line or recorded automatically. Check valves protect the gages at specimen fracture.

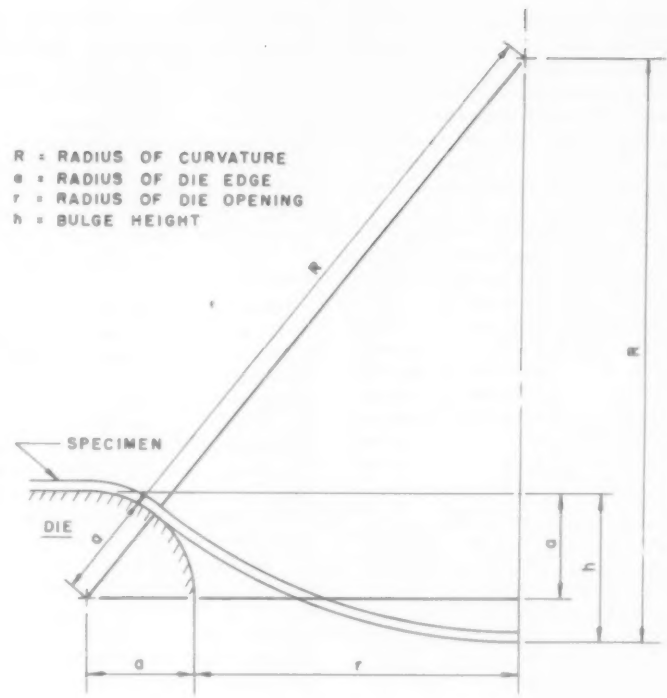
Machine Capacity

The laboratories bulge tester, in which an 8-in. diam die is clamped in a 150-ton press, will bulge 0.125-in. thick high-strength aluminum alloys without noticeable peripheral slippage. The hydraulic pressure required for bulging depends on the strength, thickness and ductility of the alloy being tested; however, a hydraulic system of 3000 psi capacity is adequate for testing welded or unwelded 0.125-in. thick aluminum alloys in this equipment.

It is difficult to estimate design values for equipment capable of testing thicker sheet. Rules developed for draw forming presses are not applicable since no slippage can be tolerated. Based on experience with 50- and 150-ton presses, it is estimated that a bulge tester for 0.250-in. aluminum alloys would require about a 400-ton press with a larger die opening of 15-25 in. to minimize the effect of bending stresses. With the larger diameter, a hydraulic pressure of 3000 psi would be completely adequate to bulge 0.250-in. plate.

Analysis of Data

Bulge test data may be analyzed to provide most of the tensile properties determined by standard ten-



(1) BASIC RELATIONSHIP: $(R+a)^2 = (r+a)^2 + (R-h+a)^2$

(2) SOLVE FOR R: $R = \frac{r^2+h^2+a^2+2ar-2ah}{2h}$

(3) SUBSTITUTE DIE DIMENSIONS: $R = \frac{h^2-2h+25}{2h}$

$a = 1"$

$r = 4"$

Fig. 3—Radius of curvature calculation

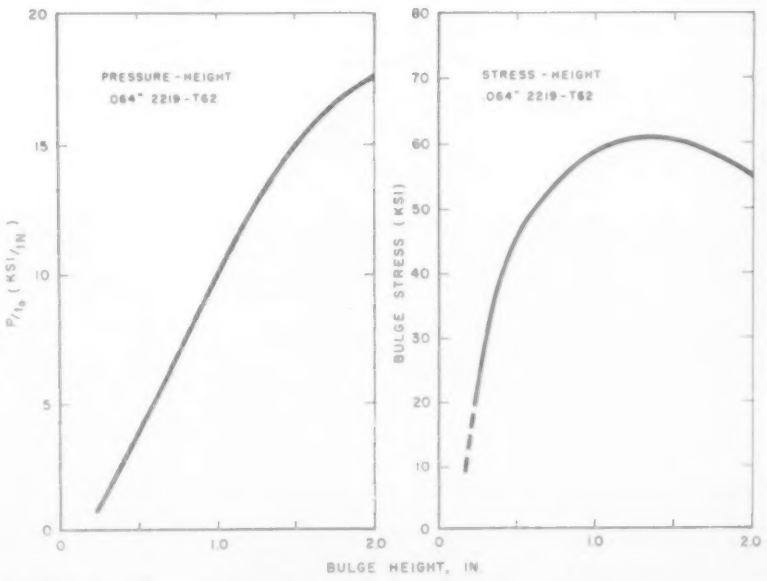


Fig. 4—Bulge data curves for 2219-T62

sile testing. Such data lend themselves to broader applications, however, since the biaxial stress system of the bulge more closely represents that encountered in pressure vessels and many other types of service loading than does the uniaxial stress system of the standard tensile specimen.

A sheet panel bulged through an open circular die generally assumes a spherical contour that decreases in radius as bulging progresses. Unless bending stresses around the clamped edge are significant, all points in the sheet are under an equal biaxial tensile stress, which can be calculated from the equation for membranes:

$$\sigma = \frac{pR}{2t_0}$$

where σ is the biaxial stress, p is the bulging pressure, R is the radius of curvature of the bulge, and t_0 is the original sheet thickness. Assuming the bulge is spherical, the radius of curvature can be calculated from the bulge height (h) with an appropriate correction for the geometry of the die, as shown in Fig. 3.

From measurements taken during the test, a pressure-height curve can be plotted—Fig. 4 (left). Because of the constantly changing curvature of the bulge, the bulge strength, i.e., the maximum tensile load, is not apparent until the data are replotted to give the more useful stress-height curve—Fig. 4 (right). It is obvious that more sophisticated instrumentation could provide direct readout of stress vs. height. For comparison, the values of maximum bulge stress and bulge height at failure are used. In general, the stress-height curve for a welded panel closely follows the curve of the parent sheet alloy, since the small weld area is restrained by the adjacent unaffected sheet. The parent sheet, however, shows more ductility, as indicated by higher bulge height, than the welded panel.

Bending stresses may lead to deviations from the spherical contour of the sheet and hence to errors in the stress values calculated by the membrane equation. These bending stresses are negligible, however, if the ratio of die diameter to sheet thickness exceeds about 200:1. They are alleviated to some extent if a generous relief radius is provided at the die entry. Errors produced by bending stresses are greatest when the bulge height is low. Consequently, errors are greater for low ductility material that bulges only slightly than for high ductility material that bulges appreciably.

The ratio of die diameter to sheet thickness of the present apparatus is 125 for 0.064-in. sheet and 64 for 0.125-in. sheet. Thus, bending stresses introduce some error in the calculated bulge stress, especially at low bulge heights. This is confirmed by measurements that show variations from spherical curvature at bulge heights less than approximately 1.5 in., but not at heights greater than 1.5 in.

The excellent agreement between calculated bulge strength and uniaxial tensile strength for unwelded sheet is shown in Fig. 5. This, of course, is expected since the unwelded sheet bulges more than 1.5 in. Correlation is also good in welded panels of alloys such as commercially pure Al and the Al–Mn, Al–Mg, and most of the Al–Mg_2Si alloys. It is not good, however, for most of the high-strength, heat-treatable alloys. In these alloys the welds and heat-affected zones have low strength or ductility. This limits the bulge height and, therefore, causes bending stresses to introduce error in the calculated bulge stress.

The fact that the bulge stress is not precisely correct, however, does not detract from the usefulness of the bulge test for comparing performance of different alloy combinations or welding procedures. Indeed, the combination of biaxial tensile stresses coupled with bending stresses is similar to that which exists in many structures and may, therefore, enhance the worth of the bulge test.

Measurements made on both welded and unwelded bulge panels show maximum straining at the center of the bulge. Consequently, the elongation depends on the gage length used, being greater for short gage lengths than for long gage lengths. On unwelded panels the elongation is essentially the same in all directions. On welded panels it

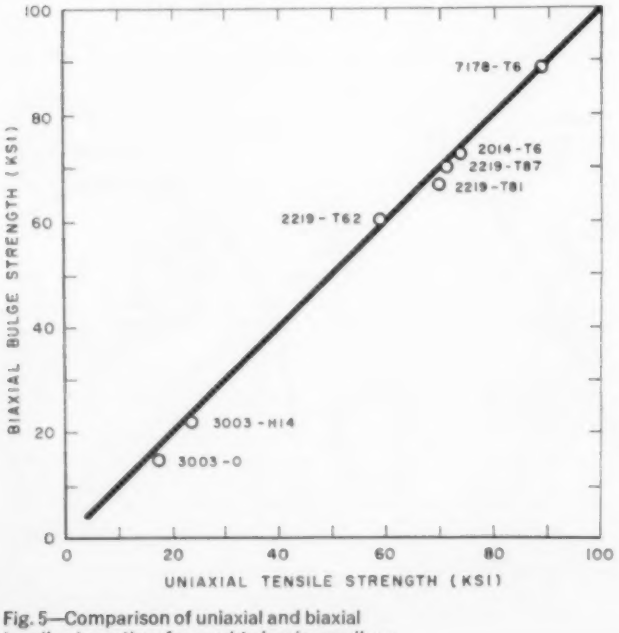


Fig. 5—Comparison of uniaxial and biaxial tensile strengths of wrought aluminum alloys

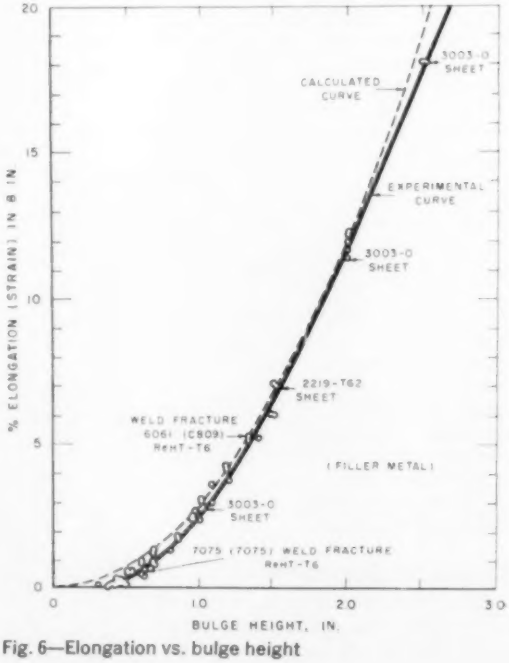


Fig. 6—Elongation vs. bulge height

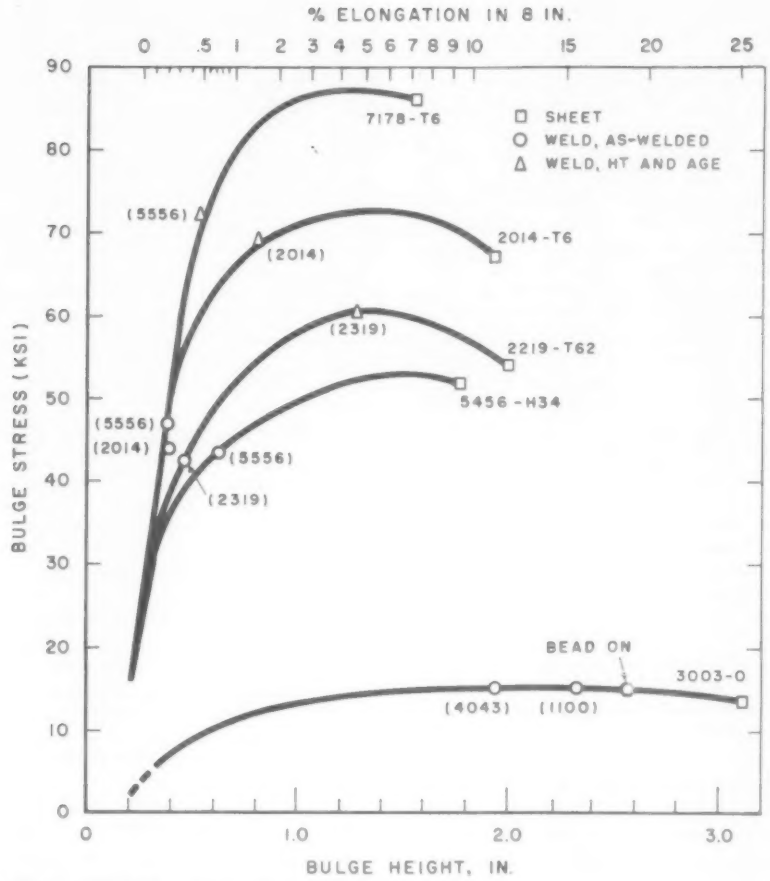


Fig. 7—Stress-height curves for welded panels

is not, because the properties of the weld and heat-affected zones adjacent to it are different from those of the parent plate.

Although cross-weld stresses can produce local preferential yielding, the elongation is essentially uniform in both directions when an 8-in. gage length is used. Such being the case, a correlation can be established between elongation in 8 in. and bulge height based on measurements from both sheet and welded panels. Measured elongations agreed well with calculated values. It should be noted that the 8-in. gage does not include the portion of the test panel that bends to conform to the inlet radius of the lower die. Therefore, measurable bulge height (approximately 0.3 in.) can be attained without significant elongation within the 8-in. gage. This is shown in Fig. 6. Similar correlations cannot be established for short gage lengths on welded panels because of the local yielding in the weld and heat-affected zones adjacent to the weld.

Typical Bulge Test Results

Bulge test results can be shown graphically by plotting the points of fracture of the welded panels on the stress-height curves for the unwelded parent sheet. This has been done in Fig. 7 for a number of alloys. In Fig. 7, the stress-bulge height curves for the unwelded sheet were first plotted. The curves for welded panels lay so close to those of unwelded sheet that only the fracture points were plotted. Percent elongation in 8 in. is plotted along with bulge height as abscissa.

In 3003-0, a low-strength ductile alloy, welds made with both 1100 and 4043 filler failed near the maximum stress, 15 ksi, of the parent sheet at elongations approximating 15%. Figure 8 shows typical 3003 bulged panels.

As-welded panels of higher strength alloys, 5456-H34* welded with 5556, 2219-T62 welded with 2319, 2014-T6 welded with 2014, and 7178-T6 welded with 5556 developed higher strength, 40–50 ksi, but failed at much lower elongations, less than 1%. With the weld bead reinforcement removed, the majority of yielding as well as the fracture occurred in the cast zone of the weld. With the reinforcement left on, the heat-affected zone yielded most and fracture occurred along the fusion line of the weld. The elongation was slightly higher when the bead was left on.

* -H34 is an experimental temper not recommended for general use.

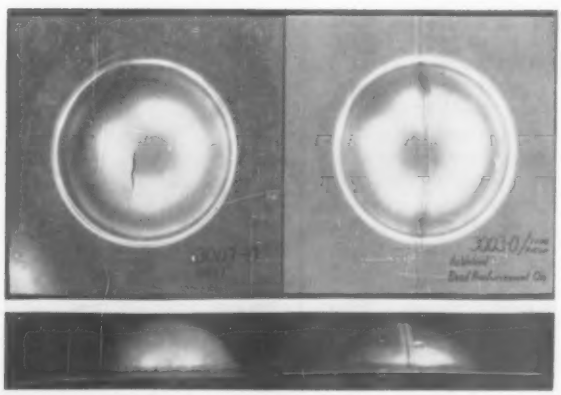


Fig. 8—Bulge test panel of 3003-0

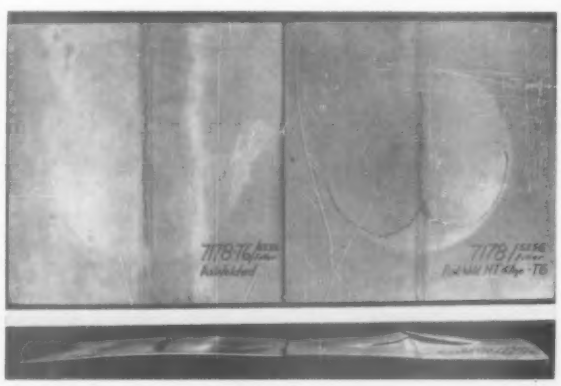


Fig. 9—Bulge test panel for 7178-T6

Reheat-treated welds in the high-strength, heat-treatable alloys varied in performance depending on the alloy. Post-weld heat-treated 7178 failed at a much higher stress than as-welded 7178, 72 ksi versus 47 ksi, but appreciably less than the ultimate sheet strength of 87 ksi. The elongation was slightly higher than for the as-welded panels. As may be seen in Fig. 9, the fracture originated in the cast zone of the weld and propagated into the sheet. Post-weld heat-treated panels of 2219 developed maximum sheet strength with failure occurring across the weld at about 4% elongation. Referring to Fig. 10, the ductility exhibited by 2219 alloy in the reheat-treated welded panels is very desirable for welded structures. Welded 2014 alloy was intermediate between 2219 and 7178 in both strength and ductility. (NOTE: Strengths shown in Fig. 7 for the post-weld heat-treated panels of 7178 and 2014 will be developed only if optimum welding procedures are used. Less refined procedures will result in failures at much lower stresses.)

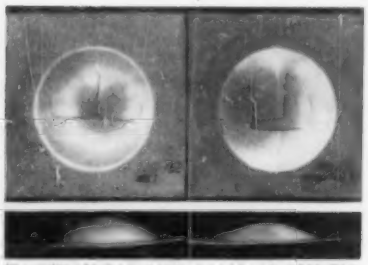


Fig. 10—Bulge test panel of 2219-T62. (Upper left—2219-T62 sheet; upper right—2219/2319 filler, post-weld HT and age. T62)

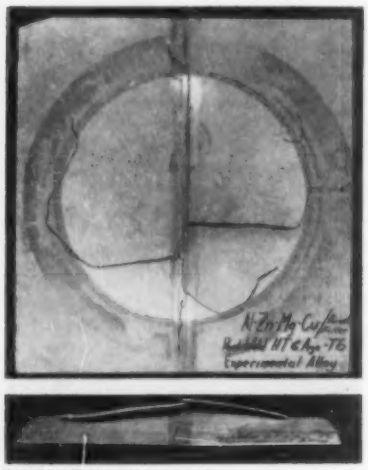


Fig. 11—Bulge test panel of experimental alloy

Drastic failures, such as shown in Fig. 11, have been encountered in some experimental alloys. Since fracture occurred at very low elongation, poor performance in welded structures would be expected from this alloy.

Application of the Bulge Test

A problem to which bulge testing was applied concerned the disagreement between tensile tests and hydrostatic tank test results. For two alloys under consideration, 2014 and 2219, typical sheet tensile strengths were 72 ksi for 2014-T6 and 65 ksi for 2219-T6E46.* Uniaxial tensile specimens from 0.125-in. thick manually welded panels gave 100% efficiency in the heat treated and aged condition for both alloys. However, tanks and cylinders of both alloys welded by the same procedures and then reheat treated gave lower strengths when tested hydrostatically. Although the results were not conclusive, tanks of 2014 usually failed at lower calculated stresses than tanks of the inherently lower strength 2219 alloy. Presumably the complex stress system in the tanks adversely affected the performance of welded 2014 more than that of welded 2219.

The results on 0.064 in. welded and heat treated bulge-test panels did approximate results obtained in tanks and cylinders. Bulge strengths of welded and reheat-treated 2219 averaged 57 ksi and of 2014, 53 ksi. These strengths indicated higher properties could be obtained in welded structures of 2219, although the sheet tensile strength of this alloy was lower than that of 2014-T6 sheet. Failure of some of the 2014 panels at the edge bend correlated well with failure of some 2014 tanks at the bend between the tank wall and the head.

A comparison of tensile and bulge data for as-welded 7075-T6 sheet with 5154 filler also showed bulge testing to be more sensitive than tensile testing for detecting the effect of differences in welding technique. Three sets of panels were made by DC straight-polarity tungsten-arc welding using 100% He, 75% He-25% A, and 25% He-

* The -T6E46 temper of 2219 is not a recommended standard temper because of questionable resistance to corrosion.

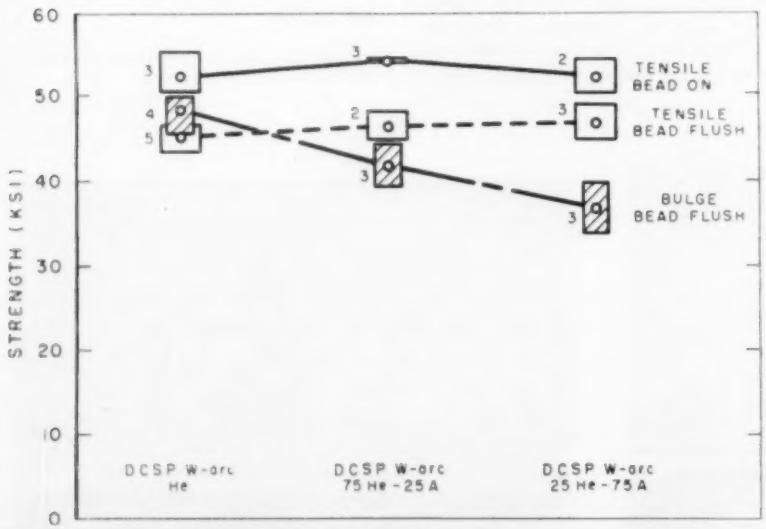


Fig. 12—Comparison of tensile and bulge strengths of as-welded 0.064 in., 7075-T6/5154 filler

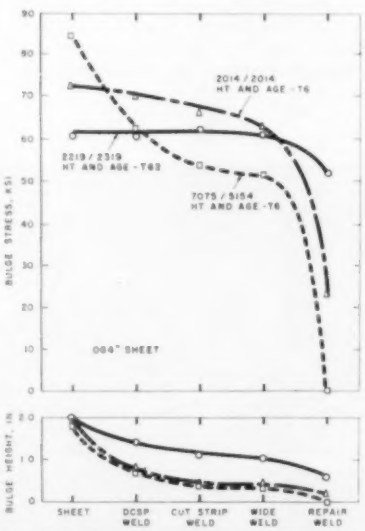


Fig. 13—Effect of welding conditions on properties obtained in bulge test

75% A, with welding conditions adjusted for the mixture being used. As shown in Fig. 12, tensile specimens for as-welded joints with all three shielding gases averaged 53 ± 2 ksi with bead on and 46 ± 2 ksi with the bead removed. In contrast, the bulge strength dropped from 48 to 42 to 37 ksi, respectively, showing that the structural strength of welds in 7075 is affected by welding technique.

Other tests on the effect of welding conditions showed automatic DC straight-polarity tungsten arc welding best and manual repair welding the worst—Fig. 13. Both of these findings are in agreement with results obtained in commercial welding of these alloys. In view of this agreement and the apparent correlation between bulge-test and tank-test results, it has been concluded that the bulge test is a good, simple test for predicting the relative performance of high-strength heat-treatable welded aluminum alloys in structures. It does not, of course, entirely eliminate the need for testing simulated or full size structures.

Summary

The hydraulic bulge test is a convenient and rapid method for predicting the relative performance of aluminum alloys in welded structures. The test specimen is simple and yet is adaptable to determining the effect of defects such as repairs, weld starts and stops, and cross welds in an appreciable length of sound weld. Stresses and elongations can be readily calculated, and the values obtained are more sensitive to welding differences than tensile test data.

Acknowledgment

The authors wish to acknowledge fundamental investigations of bulge testing conducted by Dr. Davis S. Fields. This work provided the basis for the development of the hydraulic bulge test for welds.

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WRC Bulletin No. 71

Welding Research Council Bulletin, No. 71 published in August 1961 contains the following two Reports:

Research on Tubular Connections in Structural Work by J. G. Bouwkamp and *An Investigation of Welded Steel Pipe Connections* by A. A. Toprac.

The Report, "Research on Tubular Connections in Structural Work" discusses the test results of welded structural joints of a two-dimensional truss built from steel tubes. The three connections were designed with different joint-eccentricities between the resultant of the web-member forces and the axial chord-member force. Also the results of tensile tests on four single tubes with welded transverse joints are reported herein. The joints were tested in a specially designed loading frame under a direct tensile force applied to the diagonal member by means of a 400,000-lb. hydraulic testing machine. Information on stresses were determined by means of strain gages and stress coat. Conclusions are presented concerning the effect of joint-eccentricity on the ultimate failure load for the type of joint tested.

The Report, "An Investigation of Welded Steel Pipe Connections" presents the results of an investigation on welded pipe connections. Information of ultimate strength, rigidity and rotation capacity of structural elements made of tubular sections are presented. Two of the connections were tested in a manner which produced moments that tended to open the connection legs, and the other five were tested in a manner which tended to close the connection legs. The information obtained is useful for both elastic and plastic theories of designing, and shows that there is possibility of weld failure under tension type of loading. Included in this study is the derivation of complete theoretical moment-rotation curves for pipe sections of any inside and outside diameter subjected to bending at various stages of yielding.

The price of this Bulletin is $1.50 and single copies may be purchased through the American Welding Society, 345 East 47th Street, New York 17, N. Y. Quantity lots may be purchased through the Welding Research Council, 345 E. 47th St., New York 17, N. Y.

The Welding of Titanium to Steel

Using plug welding and either conventional or series resistance welding, titanium can be readily welded to steel using vanadium as an intermediate

BY D. R. MITCHELL AND H. D. KESSLER

Introduction

Titanium exhibits outstanding resistance to many of the corrosives found in the petroleum, chemical, chlorine, pulp, paper and other industries resulting in a continually expanding market in these industries. One of the major drawbacks to its use has been cost. The cost of titanium has steadily decreased in the few short years of its existence, and it is now competitive with several of the other metals widely used in applications requiring resistance to corrosion such as tantalum and certain nickel-base alloys. Examples of such applications are chlorine cells, duct work for corrosive fumes and distillation columns, tanks and vessels for a wide variety of applications.

Cladding a thin layer of titanium to a heavier mild steel backing is a method whereby the cost of the fabrication can be reduced, but the corrosion resistance of the titanium is retained. Processes have been developed to both braze[1, 2] and roll clad[3, 4] titanium to steel, and clad products are being used in several chemical industry applications. However, clad products have several well recognized production and fabrication limitations; for this reason, other methods of using a thin section of titanium in conjunction with a heavy backing have been explored.

A modification of the use of clad material is the loose-liner approach, a procedure that has been used much more extensively in other countries than it has in the United States. A container with a loose liner many times can use much thinner titanium thicknesses than are practical with clad construction. It is not intended to discuss the merits and limitations of loose liners, although it is believed that this technique can be advantageously exploited with titanium.

It is often necessary to attach the liner to its shell, especially as the liner thickness decreases. This investigation was made to develop a method of joining titanium to steel to advance the use of thin titanium liners in process equipment. This paper discusses some of the results that were obtained.

D. R. MITCHELL and H. D. KESSLER are with the Titanium Corporation of America, Toronto, Ohio.

Paper presented at the AWS National Fall Meeting held in Dallas, Tex., during Sept. 25–28, 1961

Basic Considerations

Titanium and ferrous materials cannot be joined directly by welding, because the resultant mixture or alloy of the two metals is extremely brittle and frequently will not survive the shrinkage stresses imposed on it during cooling from the welding temperature. It is, therefore, necessary to interpose a third metal (here termed an "intermediate material") between the titanium and the steel. This metal must be compatible with both metals and must be weldable. Among the metals known to be compatible with titanium (i.e., capable of forming ductile solid solutions) are molybdenum, vanadium, aluminum and silver. However, their compatibility with steel under welding conditions was not well known and had to be determined.

Three procedures for producing joints using an intermediate material were investigated. The first method involved use of the gas tungsten-arc welding principle and was a modification of plug welding. The second method applied a conventional resistance spot welding unit and an interlayer of the intermediate material. The third method—series spot welding—was a variation of the second. The details of these processes are discussed in the following sections.

Plug Welding

Procedure

Two procedures were used to weld 0.040-in. thick commercially pure titanium to $^1/_4$-in. thick low-carbon steel. Both were modifications of plug welding using a standard gas tungsten-arc torch. Vanadium and molybdenum were investigated as the intermediate materials. Aluminum and silver were not considered because of the considerable difference between their melting temperature and those of titanium and steel.

The first method of fabrication, which was used with only the vanadium, was to bottom drill $^1/_{16}$-in. deep, a $^9/_{16}$-in. diam hole in the steel. A standard counterboring tool with a replaceable pilot drill was used for this purpose. This hole was filled by depositing two layers of vanadium using $^1/_{16}$-in. diam filler wire. A $^1/_4$-in. diam hole was drilled in the titanium, aligned concentrically with the buttered area, and welded to it using commercially pure titanium filler wire.

The second procedure was similar to the first. Instead of surfacing the mild steel, however, a solid disk of the intermediate material was inserted in the steel, flush with the top, and welded around its periphery. Both 0.062-in. thick vanadium and 0.032-in. thick molybdenum were used. As in the first procedure, the titanium was welded to the intermediate material.

Results—Molybdenum Intermediate

Four tensile shear samples were made and tested using the molybdenum disks. Tensile shear strengths of 590, 820, 870 and 1270 lb were obtained from the four specimens. Microhardness measurements were also made of a typical

weld zone; the results are shown in Table 1. It may be seen that the steel-molybdenum solid solution zone is very hard. The titanium-molybdenum zone is also harder than the base metals.

Table 1—Average Knoop Microhardness Values Across a Plug Weld Between Titanium and Carbon Steel Using a Molybdenum Button

Zone tested	Khn, 100 g
Titanium parent metal	247
Titanium button overlay	383
Titanium molybdenum solid solution	340–507
Molybdenum	260
Molybdenum-steel weld zone	854–876
Steel	155

Results—Vanadium Intermediate

During the surfacing operation used in the first procedure, a number of cracks were evident in the deposit indicating that the iron-vanadium system contains brittle compositions. However, the weld between the titanium and the deposited metal was crack-free. No cracks were found in the welds between the vanadium disks and the mild steel plates. Figure 1 presents macro-etched cross sections of the two types of joints showing the extensive cracking in the surfaced joint and the sound joint made by using the vanadium disk.

Tensile-shear tests were made on five samples of each type of assembly. One of the surfaced samples fractured while it was being stamped with a code number. The other four samples fractured in shear at the titanium-vanadium interface as shown in Fig. 2. The strength levels at which the samples fractured varied from 710 to 1100 lb with an average of 935 lb.

The vanadium disk-type samples failed by the vanadium disk pulling out at the vanadium-to-iron weld as shown in Fig. 3. The strength levels at which the samples fractured varied from 1650 to 1720 lb with an average of 1690 lb. There was only a small variance between the strengths of the disk samples as compared to the surfaced samples indicating that consistent properties could be maintained using this joint design.

A Knoop microhardness survey was made of the various critical areas, and the results are shown in Table 2. It may be seen that the

Table 2—Average Knoop Microhardness Values Across a Plug Weld Between Titanium and Carbon Steel Using a Vanadium Button

Zone tested	Khn, 100 g
Titanium parent metal	225
Titanium-vanadium solid solution	378–413
Vanadium	160
Vanadium-steel weld zone	426–605
Steel	165

two weld zones are considerably softer than the corresponding zones in the joints using molybdenum—Table 1.

As the vanadium button technique appeared most promising, an investigation was made to delineate further the factors effecting joint strengths. Variations were made in titanium thickness, vanadium thickness and the diameter of the hole in the titanium. The diameter of the vanadium disk was not changed. The depth of the counterbored hole, in relation to the vanadium disk thickness, was also varied.

For vanadium and/or titanium of 0.062 and 0.040 in. thicknesses, joint strength was independent of their thickness. The joint strengths were consistently around 1950 lb. Titanium and/or vanadium thicknesses of 0.025 in. resulted in lower joint strengths, ranging between 1000 and 1300 lb. Welds in this lightest gage were also very difficult to make and tended to burn back. Three modes of failure were found, depending upon the geometry of the joints but independent of joint strengths. When the vanadium disks were 0.062 in. thick and the titanium was either 0.062 or 0.040 in. thick, failure occurred at the vanadium-to-steel weld and the disk pulled out as shown in Fig. 3. The average strength of these joints was 1940 lb. A second type of failure

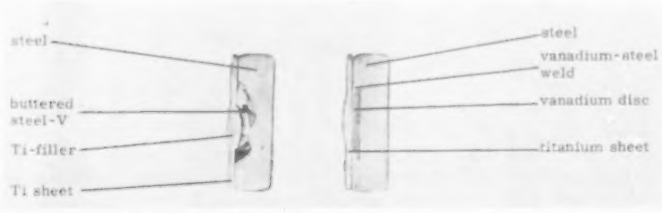

Fig. 1—Typical cross-sections of vanadium disks and surfaced type weld samples

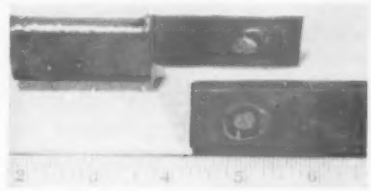

Fig. 2—Typical fracture obtained on shear tensile testing the surfaced vanadium type weld samples

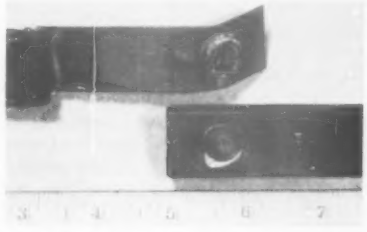

Fig. 3—Typical fracture obtained on shear tensile testing the vanadium disc type weld samples. The vanadium thickness was 0.062 in. and the titanium thickness 0.062 or 0.045 in.

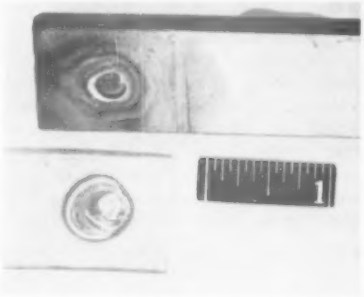

Fig. 4—Typical fracture obtained on shear tensile testing the vanadium disk type weld samples when vanadium thickness was 0.062 in. or 0.045 in. and the titanium thickness was 0.025 in.

Fig. 5—Typical fracture obtained on shear tensile testing the vanadium disk type weld samples when vanadium thickness was less than titanium thickness

is shown in Fig. 4. This type of failure occurred when the titanium was 0.025 in. thick and the vanadium was either 0.040 or 0.062 in. thick. The average strength of the joints failing in this manner was 1280 lb. A third mode of failure was noted for all other combinations of titanium and vanadium thickness in which the vanadium failed outside the weld. Although the appearance of the failures was similar, the strengths varied. Figure 5 illustrates this type of failure.

Joints were made and tested with the diameter of the hole in the titanium increased to $^3/_8$ and $^1/_2$ in. In these cases, the titanium and vanadium thicknesses were held constant at 0.062 in. With a $^3/_8$-in. hole, the average strength was 2540 lb, an increase of approximately 500 lb over similar joints with $^1/_4$-in. diam holes. With a $^1/_2$-in. diam hole, the average strength was still higher—2720 lb. Undoubtedly some of this increased strength can be attributed to the smaller bending moment caused by the decreased dislocation of the two welds in the joint. However, the closer the two welds are to each other, the greater the chance of producing a brittle weld through the formation of the brittle titanium-iron compound.

To determine how critical the depth of the counterbored hole in the steel is in relation to the thickness of the disk, holes were bored $^1/_{64}$ and $^1/_8$ in. deep. A $^1/_{16}$-in. disk was used. The average strength of the joints made with $^1/_{64}$-in. deep holes was slightly higher than normal, whereas the average strength of the joints made with $^1/_8$-in. deep holes was considerably lower, averaging approximately 20% lower than normal. It did not appear that depth was extremely critical, although care must be exercised to prevent too great a hole depth.

Spot Welding

Plug welding, using the procedure described, is an effective method of joining titanium to steel. It is, however, costly and time consuming because of the careful drilling, accurate alignment and tedious hand welding required. Resistance spot welding is much simpler as it reduces or eliminates the need for these considerations. It also may be more economical, because the minimum practical thickness of the titanium and vanadium is much less. This, of course, assumes that the necessary equipment is available.

Procedure

The basic procedure used in this investigation was to prepare a sandwich of commercially pure titanium, an intermediate material and steel. Type 302 stainless steel was used in place of carbon steel to reduce problems associated with heat balance for this preliminary investigation. The titanium was 0.062 in. thick and the stainless steel was 0.073 in. thick. Various intermediate materials were used:

1. Vanadium in thicknesses of 0.020, 0.010, 0.001 and 0.0005 in.
2. Molybdenum in thicknesses of 0.010 and 0.005 in.
3. Aluminum (2S)—0.012 in. thickness.
4. Fine silver in thicknesses of 0.020, 0.010 and 0.002 in.

A conventional 100-kva press type spot welding unit equipped with squeeze time, weld time, hold time and phase shift heat controls was used. The electrodes were RWMA, Class 3, $^5/_8$ in. diam with a 3-in. spherical tip radius. Current was measured at the primary of the transformer with a pointer stop meter and multiplied by the turns ratio to obtain the secondary current. These measurements were made prior to making the welds and, for this reason, are somewhat in error. Electrode force was measured with a compression force gage with no compensation for reactive kick. In all cases, squeeze time was 30 cycles and hold time was 60 cycles.

Tensile-shear and metallographic specimens were prepared by welding. The tensile-shear specimens consisted of 1- x 3-in. pieces of stainless steel and titanium which were lapped 1 in. with a 1- x 1-in. piece of intermediate material in between.

Results—Vanadium Intermediate

Satisfactory joints were made over a wide range of machine settings, using vanadium as the intermediate material. The majority of the welds were made with 0.020-in. thick vanadium, but a sufficient number of joints were made with 0.010-in. thick material to prove that the lighter gage is equally effective. The joints made with 0.001- and 0.0005-in. thick vanadium were generally low in strength.

Figure 6 is a plot of tension-shear strength in pounds versus the heat input for three different electrode forces using 0.020-in. thick vanadium. The heat input is calculated as the secondary current squared times the

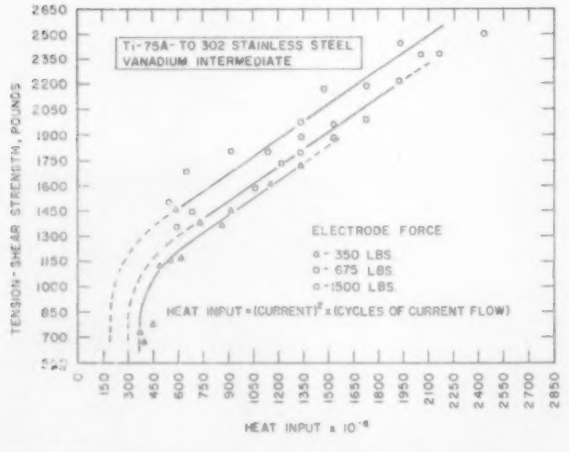
Ti-75A TO 302 STAINLESS STEEL
VANADIUM INTERMEDIATE
ELECTRODE FORCE
o - 350 LBS.
o - 675 LBS.
o - 1500 LBS.
HEAT INPUT = (CURRENT)² x (CYCLES OF CURRENT FLOW)
TENSION-SHEAR STRENGTH, POUNDS
HEAT INPUT x 10⁻⁶

Fig. 6—The effect of heat input and electrode force on tension-shear strength of resistance spot welds between Ti-75A titanium and 302 stainless steel using an intermediate layer of vanadium, 0.020 in. thick

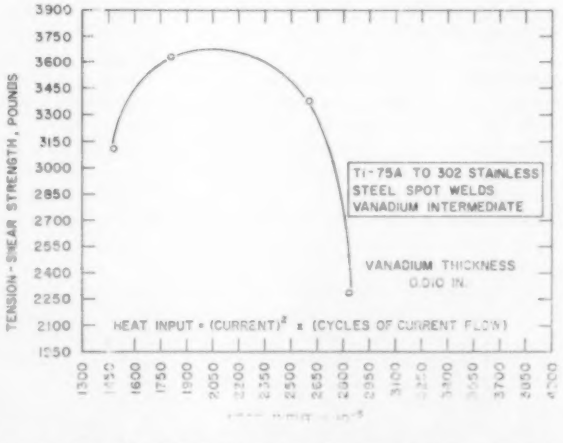

Fig. 7—The effect of heat input on the tension-shear strength of resistance spot welds between Ti-75A titanium and 302 stainless steel using an intermediate layer of vanadium, 0.010 in. thick

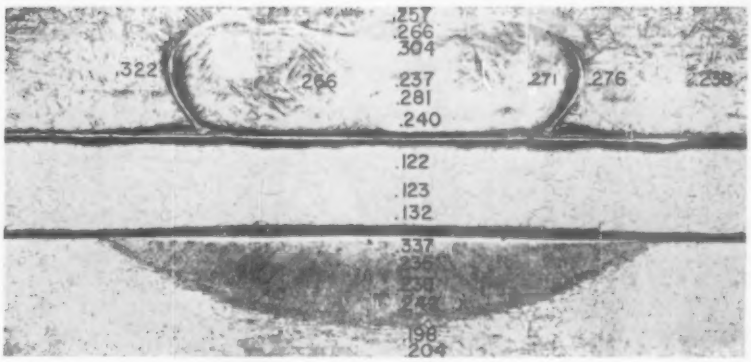

Fig. 8—Typical medium heat input spot weld between titanium and stainless steel using an intermediate layer of vanadium with Knoop hardness numbers (100 g load). × 65

Fig. 9—Typical solid solution zone between titanium and vanadium. × 450

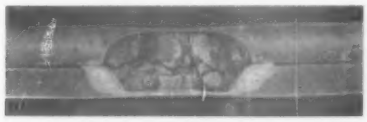

Fig. 10—Typical titanium-stainless spot weld in which complete fusion of the intermediate layer of vanadium has allowed the formation of the brittle titanium-iron eutectic structure. × 5. (Reduced 40% on reproduction)

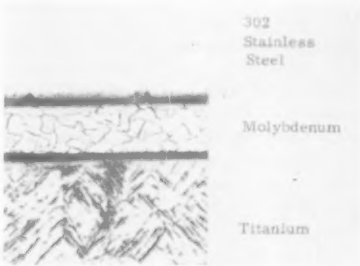

Fig. 11—Titanium-to-stainless steel spot weld using molybdenum as an intermediate layer. × 250. (Reduced approximately 42% on reproduction)

cycles of current flow. It is realized that the terms in this heat input equation are not directly relatable, but the equation was used to simplify the graph and to show the general trend of the results. It does not appear to introduce serious error. It may be seen that the strength increases linearly with heat input over most of the curve. A certain minimum heat input is required to make the welds as shown by the tailing of the curves at the low end of the heat input. The upper portion of the curves does not necessarily represent the upper limit of strength and, as will be shown, higher strengths are obtainable. Joint strength also increased with increased electrode forces. The reason for this behavior is believed to be associated with the resulting increased current flow.

Approximately one-third of the specimens tested failed at the titanium-to-vanadium interface and the remainder failed at the stainless steel-to-vanadium interface. No correlation could be seen between the type of failure and the welding conditions or strengths obtained.

Figure 7 is a plot similar to the previous graph for 0.010-in. thick vanadium. In this case, a maximum strength of slightly over 3600 lb was realized. Increasing the heat input beyond the amount required to obtain this maximum strength only decrease the strength for reasons to be explained later.

The joints made with the 0.001- and 0.0005-in. thick vanadium were generally brittle and had low and inconsistent strength values. Later investigation revealed that these joints were made with excessive currents. Successful joints could be made with these vanadium thicknesses using lower power inputs.

The metallography of the joints produced was very interesting. Examination of the most successful welds showed that there is a layer of unfused vanadium between the two welds. Figure 8 is a composite photomicrograph of a typical weld zone. The superimposed numbers are Knoop microhardness readings. Notice the absence of extremely hard phases and the relatively soft vanadium. The vanadium recrystallized in the area of the weld and grain growth occurred with no melting except at the extreme interfaces. The method of bonding is the very localized fusion of a small amount of vanadium with the titanium and stainless steel. The titanium and stainless steel have both been molten at the interfaces and have formed solid solutions with the vanadium. The vanadium has a higher melting point (3450° F) than either titanium or stainless steel (3020 and 2640° F, respectively). Figure 9 is a higher magnification photomicrograph of a solid solution zone between the titanium and vanadium. Unfortunately, satisfactory techniques were not developed to show the similar zone between the titanium and stainless steel clearly.

Increasing the heat input increases the diameter of the weld zone and, therefore, increases the strength. The amount of vanadium combined with the titanium and stainless steel also increases and the thickness of the remaining vanadium between the welds decreases. When the heat input is increased sufficiently to dissolve all the vanadium, a complex alloy of titanium, vanadium and stainless steel is formed. This alloy is extremely brittle. Figure 10 shows an example of a weld in which this has happened. This explains why the strength dropped off in welds made with 0.010-in. vanadium when the heat input was increased beyond a certain critical limit and why satisfactory welds were not made using 0.001- and 0.0005-in. thick vanadium. It is obvious that the thinner the intermediate layer the smaller must be the maximum weld diameter and the lower the strength.

Within the limits of this investigation, it was found that the machine settings for making the welds were not critical up to a certain point. Beyond this point there was a marked change in slope and increased heat input produced brittle welds.

Results—Molybdenum Intermediate

It was shown previously that molybdenum forms a very brittle phase when arc welded to carbon steel. Similar results were obtained when it was used as an intermediate material in spot welding. It does, however, satisfy some of the requirements for an intermediate material. Figure 12 is a photomicrograph of a weld zone. Small cracks can be

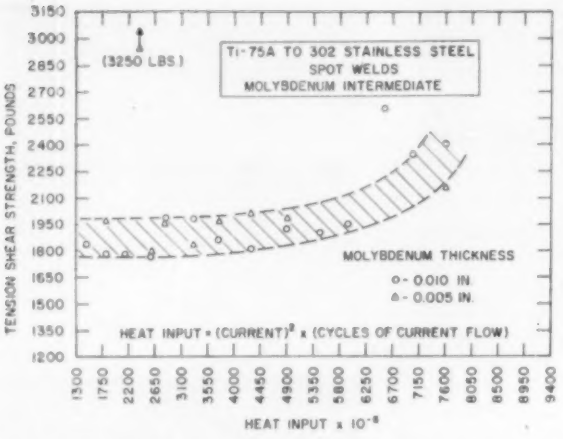

Fig. 12—The effect of heat input on tension-shear strength of resistance spot welds between Ti–75A titanium and 302 stainless steel using an intermediate layer of molybdenum

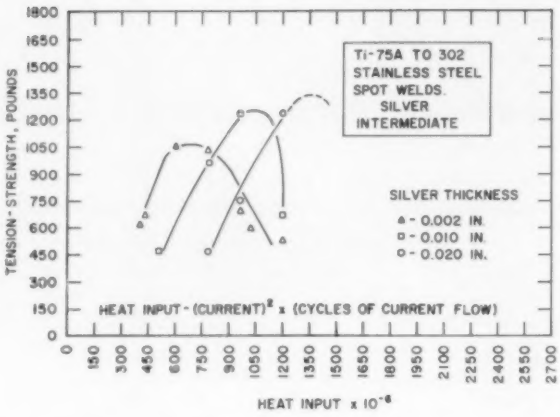

Fig. 13—The effect of heat input on tension-shear strength of resistance spot welds between Ti–75A titanium and 302 stainless steel using an intermediate layer of silver

seen extending from the molybdenum into the brittle steel-molybdenum diffusion zone. It should be noted that a solid layer of molybdenum is maintained between the titanium and stainless steel. This, as did the vanadium, prevents complete embrittlement of the weld zone due to the formation of the titanium-iron eutectic phase. This particular weld was made with a relatively low heat input, but examination of a number of welds made over a wide range of machine settings indicated that there is little tendency for this layer to melt completely. In this respect, molybdenum appears to be somewhat more versatile than vanadium; this is attributed to its higher melting point and higher electrical conductivity as compared to vanadium.

The brittle molybdenum-stainless steel diffusion zone results in inconsistent tension-shear strengths. Figure 12 is a plot of strength versus heat input for two thicknesses of molybdenum. The points are so scattered that a single curve cannot be drawn, but there is a trend toward higher strengths at the higher heat inputs. Two items are of special interest in this graph:

1. There appears to be little difference in strength (within the scatter band) between 0.005 and 0.010 in. thick molybdenum.
2. There are two strength values that are much higher than the average.

Knoop microhardness measurements were made in the various zones in a typical weld. All the zones were reasonably soft except for a very narrow band between the molybdenum and the stainless steel. Here Knoop hardnesses in excess of 1000 were found. This is the same zone showing the cracks in Fig. 11.

Results—Silver and Aluminum Intermediate

Silver and aluminum have much lower melting temperatures than either titanium or stainless steel. It would, therefore, be expected that the mechanism of bonding is different. Satisfactory joints were not obtained with either silver or aluminum. In the case of aluminum, the joints were very weak and could easily be broken by hand. The fracture appearance indicated that a brittle phase was formed with the titanium. As this welding procedure produced negative results, no further investigation was made of this combination.

Silver was evaluated as it is commonly used for brazing both titanium and stainless steel, and some researchers have shown that titanium can be brazed to stainless steel using high silver alloys.[5] The results, however, were disappointing. Figure 13 is a plot of joint strength versus heat input for the three thicknesses of silver used; it can be seen that the strengths rapidly increase to a maximum and then rapidly decrease. The range of effective heat inputs is small. The heat input at which the maximum strengths were obtained decreased as the thickness of the silver decreased. There are insufficient data to attribute any significance to the slight differences in the maximum strengths obtained.

Examination of the microstructures indicated that the silver had been completely molten and alloyed with both the titanium and the stainless steel. The majority of the alloying, however, took place with the stainless steel which has the lower melting temperature.

Figure 14 is a composite photomicrograph of a spot weld made with 0.020-in. thick silver. This particular weld was made with the same machine settings that produced the highest strength welds tested. The large void in the center was typical of the welds made with silver. Microhardness readings were taken of the various phases present, and all phases were relatively soft. Increasing the heat input, however, increases the amount of alloying and eventually a brittle phase appears

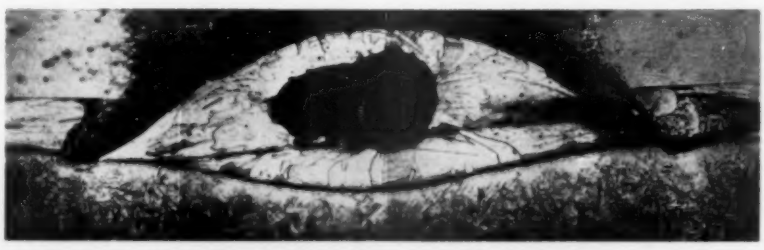

Fig. 14—Ti–75A to 302 stainless steel resistance spot weld using 0.020 in. thick fine silver as an intermediate. × 50. (Reduced 50% on reproduction)

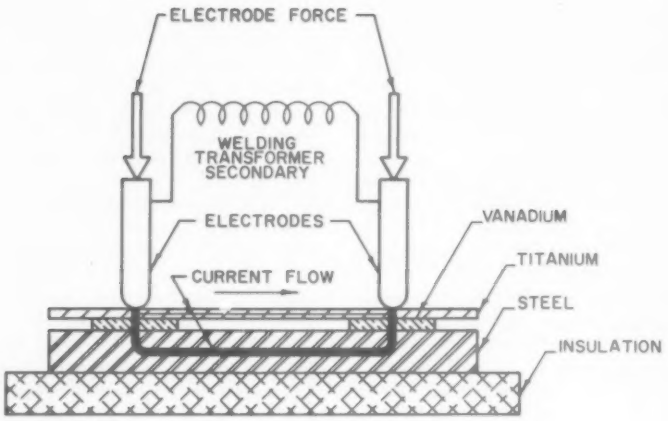

Fig. 15—Schematic diagram of a series type resistance spot weld between steel plate and titanium sheet using an intermediate layer of vanadium

and produces extensive cracking.

Another difficulty encountered was expulsion of the molten silver which was undoubtedly superheated. This probably produced the voids noted in the welds. The relatively low strengths obtained, combined with the problems of expulsion and the narrow range of effective heat input would indicate that silver is an unsatisfactory intermediate material. It may be possible, however, by reducing the heat input to produce a braze type joint. Further development effort is required in this area.

Series Spot Welding

Once it was demonstrated that the resistance spot welding of titanium to steel using an intermediate material was feasible, a simpler method of making the welds was sought. The conventional spot welding unit suffers from a lack of portability and adaptability to changing conditions. A series type spot welding unit places both electrodes on the same side of the parts to be welded and eliminates the restriction of throat depth.

Principles of Series Spot Welding

The basic principles of a series type spot weld are noted in Fig. 15. Two electrodes are used on one side of the two materials to be joined instead of the conventional method of having one electrode on either side. Current flows through the top plate into the bottom plate and through the bottom plate from the proximity of one electrode to the other and back up through the top plate to the other electrode. Two welds are, therefore, made at one time. Because the major portion of the impedence in the circuit is the inductance of the machine, only a slight increase in current flow is required over a single spot weld. Of course, a certain amount of current travels through the top plate and does not contribute to the weld. In effect, it short circuits the welds. With materials of equal thicknesses and equivalent electrical resistivity, this short circuiting current can be quite high and result in greatly increased total current requirements. The distance between the electrodes also contributes to the amount of the short circuiting current. Without going into details, it may be stated that the closer the spacing between the electrodes, the greater will be the tendency for the current to travel through the upper plate and not make a weld. This results in a minimum allowable spacing of electrodes, which may be quite large under certain conditions.

When titanium is welded to low-carbon steel, the relative resistances and current flows may be quite different. In almost all instances, the titanium will be much thinner than the steel. The titanium also has a much higher electrical resistivity than low-carbon steel. These two conditions force the majority of the current to flow through the titanium into the steel and make two welds at relatively low current values. Much closer electrode spacings may be possible in this case.

Fig. 16—Composite photomicrograph of series type resistance spot between titanium and low-carbon steel using vanadium as an intermediate. × 75. (Reduced approximately 75% on reproduction)

Procedures

The welding machine used was a laboratory model specifically designed for series welding experiments. The transformer was 70 kva. Phase shift heat control was provided along with control of squeeze, weld and hold times. The electrodes were RWMA, Class 3, with 3 in. spherical tip radii. Current was measured with a pointer stop meter during the welding. Electrode force was calibrated from the input air pressure.

Specimens were cut from the completed welds and tested in single shear in a tensile machine. Although two simultaneous welds were made, the specimens were prepared so that only one weld was tested. Metallographic samples were also prepared.

Table 3—Strength of Joints[a] Between Commercially Pure Titanium and 0.255-in. Thick Low-Carbon Steel Using a Vanadium[b] Intermediate

Titanium thickness, in.	Electrode force, lb	Electrode separation, in.	Welding current, amp	Welding time, cycles	Tension-shear strength, lb
0.025	450	3 3/4	6,900	15	1490
0.025	450	3 3/4	6,900	15	1320
0.025	450	3 3/4	6,900	15	1433
0.025	450	2 1/2	6,900	15	1725
0.025	450	2 1/2	6,900	15	1508
0.025	110	2 1/2	6,100	15	625
0.025	110	2 1/2	6,100	15	1325
0.025	110	2 1/2	6,100	15	1342
0.062	675	2 1/2	10,300	15	2730
0.062	675	2 1/2	10,300	15	2785
0.062	375	2 1/2	10,300	15	3080
0.062	375	2 1/2	10,300	15	3120
0.062	375	2 1/2	10,300	15	3110
0.062	375	2 1/2	10,300	15	3122

[a] Series type resistance spot weld.
[b] Vanadium was 0.010 in. thick.

Results

Some of the tension-shear test results are shown in Table 3. The joints generally failed by shearing at the interfaces. It may be seen that excellent shear strengths were developed. Electrode spacing was not critical down to 2½ in. Closer electrode spacings were not physically possible with the equipment available. It is interesting to note the relatively low electrode forces that were used. Electrode forces several times higher than these are commonly recommended for welding stainless steel. This would reduce the need for heavy force bucking equipment. One low strength value of 625 lb is shown which will be discussed later.

Figure 16 is a composite photomicrograph of a series spot-welded titanium-to-steel joint using an intermediate layer of vanadium. This particular joint was made using 0.025-in. thick commercially pure titanium, 0.010-in. thick vanadium and ¼-in. thick mild steel. Figure 16 is similar to Fig. 8 except that the solid solution zone between the iron-rich vanadium-steel solid solution zone is much larger. A very narrow band of vanadium-rich vanadium-iron solid solution extends along the weld next to the vanadium which tended to overetch and shows up as a dark shadow. A series of microhardness measurements were made across the weld, and this phase proved to have the greatest hardness. It measured 370–390 on the Knoop scale. All other phases were considerably softer. Although direct comparisons are impossible to make, the Knoop hardness of the vanadium-steel weld zone would roughly correspond to a Rc hardness in the high thirties.

The one low strength value previously noted is believed to be due to the complete fusion of the vanadium and the formation of a brittle titanium-iron-vanadium alloy. The complete fusion of the vanadium, in turn, was the direct result of the low electrode force.

All other things being equal, as the electrode force increases, the resistance of the joint decreases which would tend to increase the current flow. However, most of the secondary impedence of the welding circuit is in the reactance and resistance of the welding machine. The resistance of the joint is a small percentage of the total impedence. An increase in electrode force, therefore, changes the welding current only slightly and the heat generated at the interfaces is almost directly proportional (within limits) to the electrode force.

When low electrode forces are used, the resistance of the interfaces will be high and may vary considerably from weld to weld. When the welding currents and times are such that the heat input is very nearly enough to completely melt the vanadium, a brittle joint may be formed. It is believed better, therefore, to reduce the welding current and/or time to a value less than optimum to reduce or eliminate the possibility of forming bad joints. This practice would result in a decrease in average joint strength but would greatly increase reliability. It should be pointed out that increasing the electrode force will also increase the reliability by averaging out some of the variables that effect joint resistance.

Summary

Titanium can be readily joined to steel using a suitable intermediate material. Vanadium has proved to be the best of several intermediate materials tested. Three methods of producing joints were investigated; these were (*a*) plug welding, (*b*) conventional resistance spot welding and (*c*) series resistance spot welding. All can produce satisfactory joints.

The relative merits of these methods of joining titanium to steel—and, in fact, the desirability of doing so—can only be determined by field trials. Titanium-clad steel may prove to be satisfactory in many applications. There are several manufacturers of titanium-clad steel, and chemical equipment has been fabricated with this product. Process equipment fabricated by the methods described in this paper has also been made and is under evaluation.

Acknowledgments

The authors wish to acknowledge the contributions of R. E. Kutchera, formerly of TMCA, who conducted the early phases of this investigation, R. Solomon of Allegheny Ludlum Steel Corp. who assisted in the preparation of the single spot welds and E. Harris and W. F. Haessly of the Taylor-Winfield Corp. who assisted in the preparation of the series spot welds.

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Investigation of Residual Stresses by Use of Hydrogen Cracking

Systematic crack pattern results when charging heat-treated SAE 4340 steel weldment with hydrogen; and mathematical equations express relation residual-stress distribution and crack pattern

BY KOICHI MASUBUCHI AND D. C. MARTIN

ABSTRACT. The objective of this research was to determine whether hydrogen-induced cracking could be used as a method of studying residual-stress patterns in welded joints.

Investigations were conducted on simple weldments made with several types of steel, including mild steel (ABS Class B), low-alloy high-strength steel (HY-80), a commercial high-strength heat-treated structural steel, and ultrahigh-strength steel (SAE 4340) to determine whether cracking would occur during hydrogen charging as a result of the residual stress. It was found that systematic crack patterns could be produced in weldments made with SAE 4340 steel plate heat treated to a high strength level. In steels of lower strength, a systematic crack pattern was not produced by hydrogen charging.

Hydrogen-induced-cracking tests were conducted on several complex weldments made with heat-treated SAE 4340 steel. Complex butt joints, a circular-groove weld, continuous and intermittent fillet joints and complex structures were tested. Various crack patterns that could be related to the residual-stress distribution were obtained.

Mechanically stress-relieved specimens also were tested to determine whether hydrogen-induced cracking was stress sensitive or plastic-strain sensitive. The test results have shown that the hydrogen-induced cracking was mainly stress sensitive.

The results of the hydrogen-induced-cracking tests have shown that the technique could be used to study the residual stress patterns in a complex weldment.

Stress-corrosion-cracking tests also were conducted on weldments made with mild steel and several types of high-strength steel. Cracks were obtained in most of the specimens. Systematic crack patterns were observed in the specimen made with the commercial high-strength heat-treated structural steel. The crack patterns were similar to those obtained in SAE 4340 steel specimens charged with hydrogen. Systematic crack patterns were not observed when other base steels were used.

Analytical investigations of crack patterns were made. Mathematical equations to express the relation between the residual-stress distribution and the crack pattern have been developed. Numerical analyses also were made of crack patterns in simple stress fields.

KOICHI MASUBUCHI is Chief of The Design and Methods of Fabrication Section, Welding Div. of the Transportation Technical Research Institute, Tokyo, Japan, and is a Visiting Research Fellow at Battelle Memorial Institute, Columbus, Ohio. D. C. MARTIN is also with the Battelle Memorial Institute.

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Introduction

Various techniques have been developed using mechanical and electric strain gages to measure residual stress in a welded joint. By using these techniques, it is possible to determine the distribution of residual stresses in a simple weldment like a butt weld. However, when a more complex joint is considered, the measurement of residual stresses becomes extremely difficult. Photoelastic techniques have been used in determining stress distribution in various structures. However, the high temperatures encountered during welding make it impossible to use these techniques in the study of residual stresses in a complex weldment.

Considerable research has been carried out on the hydrogen-induced delayed fracture of high-strength steels in connection with the causes of fracture in high-strength aircraft parts. The results of the research have shown that in hydrogen-embrittled steels:

1. Fracture occurs at stresses far below the yield stress of the material.

2. Cracks induced by hydrogen are always at 90 deg to the principal stress.

These findings indicated that hydrogen-induced cracking might provide a good method for studying residual stresses. It was hypothesized that charging a weldment containing residual stresses with hydrogen might cause a crack pattern which could be related to the residual-stress pattern. If this were so, the technique would be suitable for studying the complex residual-stress system that exists in complex welded structures.

Experiments on Hydrogen-induced-cracking Technique

Background and Objective

Previous research has shown that the type of material has considerable effect on the hydrogen-induced delayed fracture characteristics. Simcoe, *et al.*,[1] conducted fracture tests on specimens made with SAE 4340 steel heat treated to various strength levels while the specimens were cathodically charged with hydrogen. It was found that as strength level increased, fracture occurred at a lower stress level in a shorter time.

Investigations first were conducted on simple weldments made with several types of steel to determine whether cracking would occur

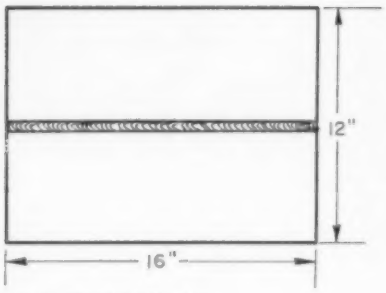
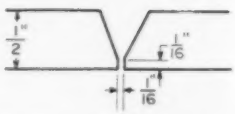


Fig. 1—Simple butt joint



Joint details for $\frac{1}{2}$-inch-thick plate

upon hydrogen charging as a result of residual stresses. Later, investigations were carried out on more complex joints.

Method of Experiment

Steel Plate and Heat Treatment. The following four types of steel were used:

1. Mild steel, ABS Class B (approximate tensile strength — 75,000 psi).
2. Low-alloy high-strength steel, HY-80 (approximate tensile strength—100,000 psi).
3. A commercial high-strength heat-treated structural steel (approximate tensile strength —120,000 psi).
4. Ultrahigh-strength steel, SAE 4340 (approximate tensile strength—150,000 psi in as-rolled condition).

The following two heat treatments were used for the commercial high-strength heat-treated structural steel specimens prior to welding:

1. Soft Condition — Water quenched from 1650° F and tempered at 1150° F for 1 hour (approximate tensile strength —120,000 psi).
2. Hard Condition — Water quenched from 1650° F and tempered at 350° F for 1 hour (approximate tensile strength—150,000 psi or higher)

SAE 4340 steel specimens were oil quenched from 1550° F and tempered at 500° F for 1 hour (approximate tensile strength—250,000 psi or higher). One specimen was tempered at 600° F.

Types of Specimen and Welding Techniques. Experiments were conducted on the following types of specimens:

1. Simple butt joints.
2. Slit-type specimens and bead-on-plate specimens.
3. Butt joints with repair welding and cross-butt joints.
4. Circular-groove weld specimens.
5. Fillet joints.
6. Complex structures.

The simple butt joint (for $\frac{1}{2}$ in. thick plate) was shown in Fig. 1.

Most of the specimens were made with manual covered electrode welding. The electrodes used for each type of steel were as follows:

1. ABS B steel—E6010 and E-7010.
2. HY-80 steel—E10016.
3. Commercial high-strength heat-treated structural steel—E10016 and E12015.
4. SAE 4340 steel—E15016.

Most specimens made with SAE 4340 steel were welded with 400° F preheat and interpass temperature. A preheat and interpass temperature of 350° F was used on small-size specimens (bead-on plate specimens), used in the experiments on mechanical stress relieving. Preheat was not used with the other base plates.

Hydrogen Charging. After welding, each specimen was charged with hydrogen. In most cases, exposed surfaces of a specimen were ground prior to hydrogen charging to get a smooth, clean surface. Electropolishing also was used on some specimens to remove the thin layer affected by grinding and to eliminate the effect of residual stresses caused by the grinding operation.

Specimens were charged with hydrogen by immersing in an electrolyte with the specimen as the cathode of a cell. The anode was a set of lead strips. The standard charging conditions were:

1. Electrolyte—4% H_2SO_4 (approximately 200 ls in volume), to which was added 5 drops per liter of poison. The poison was 2 g of phosphorus dissolved in 40 ml of carbon disulfide.

2. Current Density—0.35 to 0.8 amp per sq in. of exposed specimen surface.

Inspection for Cracking. After hydrogen-charging treatments, the specimens were inspected for cracking. Liquid-penetrant and radiographic inspection were used. Some specimens were radiographed before and after hydrogen charging. No cracks were found in the specimen before hydrogen charging.

Fig. 2—Crack pattern in simple butt joint (specimen P4-3) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test

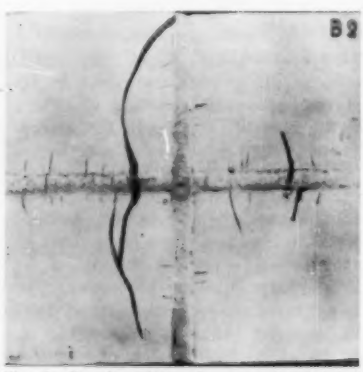


Fig. 3—Crack pattern in cross-butt joint (specimen B23) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test

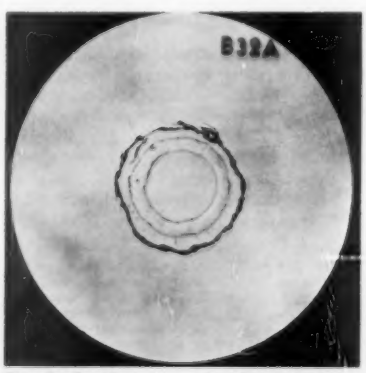


Fig. 4—Crack pattern in circular-groove weld (specimen B32) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test

Results of Experiment

Results of the hydrogen-induced cracking tests are summarized in Table 1. The information obtained from these tests is discussed in the following sections.

Effect of Types of Steel.

1. ABS Class B Steel. Four specimens were tested. No cracks were found even after 126½ hr of charging.

2. HY-80 Steel. Three specimens were tested. Small cracks in the heat-affected zone were found in one specimen after charging for 22 hr. No cracks were observed in the other two specimens.

3. Commercial High-strength Heat-treated Structural Steel, "Soft" Condition. One specimen was tested. No crack was observed after charging for 4½ hr.

4. Commercial High-strength Heat-treated Structural Steel, "Hard" Condition. Five specimens were tested. Cracks were found in three specimens.

5. SAE 4340 Steel, as Rolled. One specimen was tested. No crack was observed after charging for 14 hr.

6. SAE 4340 Steel, Heat Treated. Nineteen specimens of various types were tested. The charging time ranged from 1 to 16 hr. Extensive cracks were found in all specimens except in one that had been stress relieved mechanically before charging. The crack patterns were regular.

Test Results on Various Joints. Hydrogen-induced-cracking tests were conducted on various types of joint designs to determine how the crack pattern would change as the joint design changed. All of these specimens were made with SAE 4340 steel heat treated to a high-strength level.

1. Simple Butt Joints. Four simple butt joints were tested. A system of periodic transverse cracks, as shown in Fig. 2, was obtained in all specimens. Characteristics of the crack patterns, such as the length and the interval of cracks, were fairly consistent among the specimens tested. The length of cracks was short in the region near both edges of the specimen. These transverse cracks were probably caused by the high-tensile longitudinal residual stresses that were present in the vicinity of the weld.

2. Complex Butt Joints and Circular-groove Weld. Tests were made on the following weldments:

(*a*) Butt joint with repair welding. The weld metal in the center 6 in. of a simple butt joint was removed for about a depth of 3/16 in. from both surfaces. These grooves were rewelded.

(*b*) Cross-butt joint, ½ x 12 x 16 in.—Fig. 3.

(*c*) Circular-groove weld—Fig. 4. Circular grooves, 3 in. diam, 15/64 in. deep, 60-deg. included angle, were made on both surfaces of a circular plate, 12 in. diam.

In the butt-weld specimens, there was a series of cracks transverse to the weld, including the transversely intersecting butt weld in the cross-butt joint. There was a long parabolic crack starting from one end of the repair weld in the repair-welded specimen. Widely extended cracks parallel to the weld were observed in the repair-welded specimen and in the cross-butt joint.

In the circular-groove weld, the major crack was a circular one surrounding the groove weld, as shown in Fig. 4. This specimen also contained a system of short radial cracks in one surface.

3. Fillet Joints. Four 18 in. long fillet joints were tested. The specimens were welded by the following procedures:

(*a*) Heavy, continuous welding.
(*b*) Light, continuous welding.
(*c*) Heavy, intermittent welding.
(*d*) Light, intermittent welding.

The heavy welds were made in six passes, while one pass was used to make the light weld.

There was a series of short cracks transverse to the welding direction on the welded side in the specimens welded by the continuous-welding procedure, as shown in Fig. 5. The transverse cracks consisted of two different sets of cracks. One was shorter and rather closely spaced, and the other, longer and more widely spaced. Different crack patterns were obtained on the unwelded back surface. Transverse cracks on the back surface of the light continuous weld appear to correspond to the longer, more widely spaced cracks on the welded side. In the heavy, continuous weld specimen several longitudinal cracks were found on the back surface.

In the heavy, intermittent weld specimen, curved cracks were observed at the ends of each fillet weld, as shown in Fig. 6. Curved cracks around the fillet weld also were observed on the back surface. Tiny transverse cracks alongside the fillet welds were found on the front surface and longitudinal cracks connecting the curved cracks were found on the back surface. In the light, intermittent weld specimen, both curved cracks at the ends of

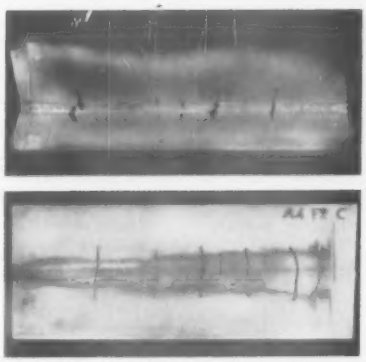


Fig. 5—Crack pattern in light, continuous fillet joint (specimen A4-F2) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test

Fig. 6—Crack pattern in heavy, intermittent fillet joint (specimen A4-F3) heat-treated SAE 4340 steel after hydrogen-induced-cracking test

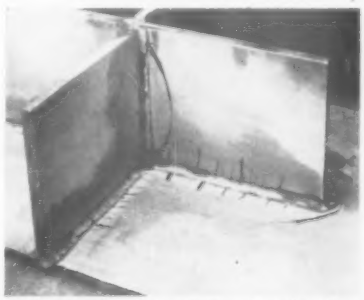


Fig. 7—Crack pattern in complex structure with directly intersecting frames (specimen B11) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test

Fig. 8—Crack pattern in complex structure with cutout transverse and longitudinal plates (specimen B13) of heat-treated SAE 4340 steel after hydrogen-induced-cracking test (front surface)

Table 1—Summary of Hydrogen-induced-cracking-test Results

Specimen	Plate thickness, in.	Treatment prior to welding	Type of specimen, welding techniques, and other experimental conditions	Charging current, amp.	Duration of charging, hr.	Results
Mild steel, ABS Class B						
PB-1	3/4	As flame cut	Slit-type specimen[a] (manual arc welding)		20	No crack
PB-2	3/4	Stress relieved			18 1/2	No crack
FM6[b]	1/2	Stress relieved	Simple butt joint, submerged-arc welding	300	47	No crack
FM8[b]	1/2	As flame cut	Simple butt joint, manual arc welding		126 1/2	No crack
Low-alloy high-strength steel, HY-80						
PH-1	1/2	As flame cut	Slit-type specimen (manual arc welding)	300	20	No crack
PH-2	1 1/2	Stress relieved			22	Small cracks in heat-affected zone
FH2[b]	1/2	As flame cut	Simple butt joint, manual arc welding		140 1/2	No crack
Commercial high-strength heat-treated structural steel						
AT-B3	3/4	Soft condition	Simple butt joint, manual arc welding		4 1/2	No crack
AT-B1	3/4	Hard condition	Butt joint with repair welding		5	No crack
AT-B2	3/4		Simple butt joint, manual arc welding		15	No crack
AT-F1	3/4		Fillet joint (heavy, continuous)	300	18	Longitudinal crack in bottom plate
FT2	1/2				7 3/4	Cracks were observed after 24 hr (without charging after 7 3/4 hr)
FT3[b]	1/2		Simple butt joint, manual arc welding		24	One crack extended greatly in the last 7 1/2 hr of charging
Ultrahigh-strength steel, SAE 4340						
Simple butt joints or slit-type specimens						
P4-1	3/4	As rolled	Slit-type specimen, inert-gas shield[c]		14	No crack
P4-3	1/2	Heat treated	Simple butt joint, manual arc welding		1	Cracked (Fig. 2)
F45[b]			Simple butt joint, inert-gas shield[c]	300	7	Cracked
F47					2 3/4	Cracked
F49[b]			Simple butt joint, manual arc welding		7 1/2	Cracked
Complex joints (manual arc welding)						
B21-1	1/2	Heat treated	Butt joint with repair welding	250	5	Cracked
B23			Cross-butt joint	270	3	Cracked (Fig. 3)
B32			Circular-groove weld	150	4 1/2	Cracked (Fig. 4)
A4-F1	5/8	Heat treated	Fillet joint (heavy, continuous)	300	16	Cracked
A4-F2			Fillet joint (light, continuous)		6	Cracked (Fig. 5)
A4-F3			Fillet joint (heavy, intermittent)		6 1/2	Cracked (Fig. 6)
A4-F4			Fillet joint (light, intermittent)		15	Cracked
Complex structures (manual arc welding)						
B11	1/2	Heat treated	Longitudinal and transverse frames intersect directly	350	3	Cracked (Fig. 7)
B12			Cut-outs in transverse frames		2 1/2	Cracked
B13			Cut-outs in longitudinal and transverse frames		2 1/2	Cracked (Fig. 8)
Tests on effect of mechanical stress relieving						
D8	1/4[d]	Heat treated	Bead-on plate, As welded	75	6	Cracked
D3			20% yield			Cracked
D4			40% yield			Cracked
D5			60% yield			Cracked
D6			80% yield			No crack

[a] A 6 in. long double vee-shaped slit was made in a 12 x 16 in. plate.
[b] Specimens were inspected radiographically before hydrogen charging.
[c] Inert-gas metal-arc process.
[d] Plates were ground to 1/4 from 1/2-in. plates.

the welds and transverse cracks were found. However, these cracks were not so predominant as those observed in other specimens. This appears to be a result of the lower residual stress in the specimen made with a minimum of welding.

4. Complex Structures. Three types of complex structures which simulated intersections of longitudinal and transverse members of a ship were prepared with 1/2 in. thick plate. In Specimen B11, which simulated an intersection between two watertight bulkheads, transverse and longitudinal plates directly intersected each other—Fig. 7. In Specimen B12, which simulated an intersection between a longitudinal girder and a transverse frame, a 2 in. radius cutout was made in the transverse plates at the corner of the intersection. In Specimen B13, which simulated an intersection between two nonwatertight frames, 2 in. radius cutouts were made in both the transverse and longitudinal plates—Fig. 8. In all specimens, a frame was made by a longitudinal through plate and two transverse plates. One end of the longitudinal plate continued to a free edge of the bottom plate, while the other end stopped short of the opposite free edge of the bottom plate, making an abrupt structural discontinuity.

A system of short transverse cracks was found along most fillet welds. The transverse cracks consisted of two different series, short, closely spaced cracks and longer, more widely spaced ones. Transverse cracks also were found on the back surface of the bottom plate. These corresponded approximately to the cracks which had wider spacing on the front surface.

Differences were found in the distribution of transverse cracks among the three types of fillet welds of a specimen. Transverse cracks were most predominant in fillet welds between the longitudinal (through) plate and the bottom plate, less predominant in the fillet welds between the transverse (interrupted) plate and the bottom plate, and least predominant in the welds between the transverse and longitudinal plates. The decrease in number of transverse cracks in these joints may be caused by release of residual stresses as a result of the formation of other types of cracks in the vicinity of these welds.

Parabolic cracks were found in the vicinity of every structural discontinuity. These cracks were much longer than the transverse cracks, and they appeared in the plate to which the edge of another plate was joined.

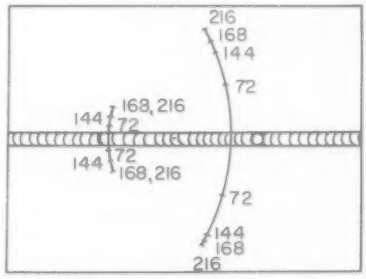
In the region near the intersection of the longitudinal and transverse frames, slightly curved, radial cracks were found at the center of the cutout (Specimens B12 and B13), while a slightly curved crack parallel to the weld was found in the longitudinal plate in Specimen B11.

Effect of Mechanical Stress Relieving. There was some question as to whether the cracks caused by hydrogen charging welded specimens were caused by residual stress due to welding or by plastic deformation produced in the vicinity of the weld during welding. Hydrogen-induced-cracking tests of mechanically stress-relieved specimens were conducted to obtain some information on this question.

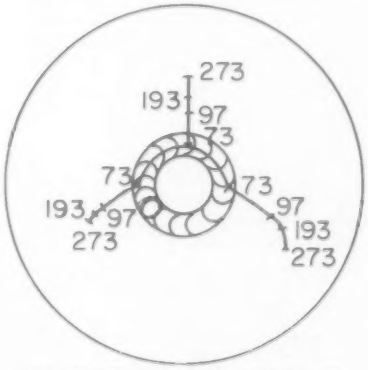
As the longitudinal tensile residual stress in the region near the weld is usually as high as the yield stress of the material, additional plastic deformation occurs in that region when a tensile load in the longitudinal direction is applied to a welded specimen. However, the magnitude of residual stress decreases because of this additional plastic strain. This phenomenon is known as "mechanical stress relieving." If hydrogen induced cracking is sensitive to plastic strain, more cracking should occur in mechanically stress-relieved specimens than in as-welded specimens. If hydrogen cracking is sensitive to stress, there should be less cracking in mechanically stress-relieved specimens.

Bead-on-plate specimens, 3 1/2 by 16 in., were prepared from 1/2 in. thick plate. A 9 in. long section in the center of the specimen was reduced to 1/4 in. thickness by grinding before welding. Specimens were welded by using manual arc welding to lay a longitudinal weld bead on both surfaces of the specimen. After welding, specimens were mechanically stress relieved by loading in a testing machine to various stress levels.

A series of regularly spaced transverse cracks was obtained in the as-welded specimen and the specimens which had been loaded to 20 and 40% of the yield stress. In the specimen loaded to 60% of the yield stress, the interval of cracks seemed to be a little wider than that of cracks in as-welded specimens and specimens stress relieved to a lower level. Transverse cracks were not found in the specimen which had been loaded to 80% of the yield stress.



(a) Simple butt joint, specimen C1



(b) Circular-groove weld, specimen C3

Fig. 9—Growth of stress-corrosion cracks in mild-steel specimens. (The numbers in the figure show the duration of a stress-corrosion-cracking test in hours)

Experiments on Stress-corrosion-cracking Technique

Background and Objective

McKinsey[2] obtained a system of transverse cracks in a butt joint using a stress-corrosion-cracking technique. Recently, Rädeker[3] reported a study of the use of the stress-corrosion-cracking technique as a method to prove the existence of residual stresses in a welded joint.

Comparative studies of the hydrogen-induced-cracking technique and the stress-corrosion-cracking technique were conducted to learn whether the crack patterns produced by stress corrosion are similar to those obtained by hydrogen charging.

Method of Experiment

Ten specimens were prepared. Five were made with mild steel ABS Class B, and the other five were made with three different high-strength steels:

1. HY-80 steel.
2. Commercial high-strength heat-treated structural steel, hard condition.
3. SAE 4340 steel heat treated to a high-strength level.

Specimens were immersed in a boiling aqueous solution consisting

of 60% of $Ca(NO_3)_2$ and 4% of NH_4NO_3. After testing for a certain period, the specimens were inspected for cracking.

Experiment Results

Results of the stress-corrosion-cracking tests are summarized in Table 2 and discussed briefly in the following.

Mild-steel Specimens. Cracks were found in two out of the five specimens tested. In these specimens cracks did not occur during the first 48 hr of testing. Cracks first appeared after about 72 hr of testing. They grew gradually thereafter, as shown in Fig. 9. Cracks were not observed, however, in the other specimens even though they were tested 201 to 400 hr.

High-strength-steel Specimens. Cracks were found in all specimens made with high-strength steels.

In the HY-80 steel specimen, one transverse crack about 5 in. long was observed after 68 hr of testing. As testing continued, the crack gradually extended and two more cracks occurred.

A fairly systematic crack pattern was obtained in the specimen made with the commercial high-strength heat-treated structural steel, as shown in Fig. 10. The crack pattern was very similar to that produced in SAE 4340 steel specimens which were hydrogen charged. The cracks were obtained in a fairly short testing period, and occurred at some time between 0 and 23 1/2 hr of testing.

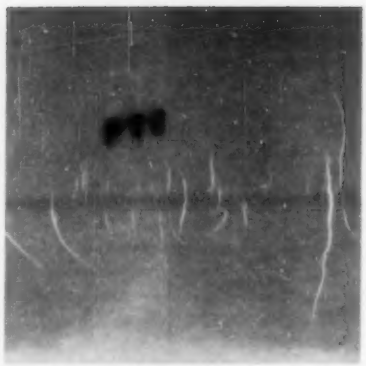


Fig. 10—Radiograph of simple butt joint (specimen FT1) of commercial high-strength, heat-treated structural steel treated to "hard condition" after stress-corrosion-cracking test

Cracks also were found in SAE 4340 steel specimens. However, the crack patterns were not systematic or consistent. The cracks observed in Specimens F41 and F43 are very similar. However, a different crack pattern was obtained in Specimen F48. In this specimen one long crack was first observed after 205 1/2 hr of testing. This extended gradually as the test was continued; another crack was observed after 253 1/2 hr of testing.

Summary of Experimental Findings

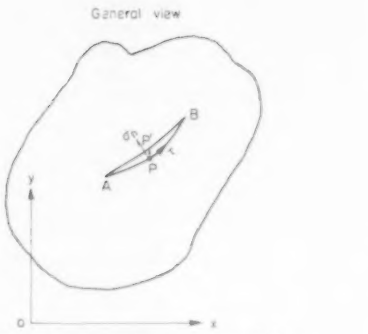
Hydrogen-Induced-Cracking Test

Effect of Type of Steel. Systematic crack patterns were found only in specimens made with SAE 4340 steel heat treated to a high-strength level. Cracks also were found in some specimens made with a commercial high-strength heat-treated structural steel treated to the hard condition; however, crack patterns were not so systematic. Small cracks in the heat-affected zone were found in one specimen made with HY-80 steel. No cracks were observed in mild steel specimens. From these results, it can be concluded that the hydrogen-induced cracking technique applies only to high-strength steels, such as the heat treated SAE 4340 type.

Table 2—Summary of Stress-corrosion-cracking-test Results

Specimen	Plate thickness, in.	Material	Type of specimen and welding technique	Duration of testing, hr: Last checking time before cracking	First checking time after cracking	Total testing time	Results
Mild steel, ABS Class B							
C1	3/4	ABS Class B	Simple butt joint, manual arc welding	48	72	240	Two transverse cracks (Fig. 9a)
C2	3/4	ABS Class B	Straight-groove weld,[a] manual arc welding	201	...	201	No crack
C3	3/4	ABS Class B	Circular-groove weld,[b] manual arc welding	49	73	273	Three radial cracks (Fig. 9b)
FM5	1/2	ABS Class B	Simple butt joint, submerged-arc welding	230	...	230	No crack
FM7	1/2	ABS Class B	Simple butt joint, manual arc welding	400	...	400	No crack
High-strength steels							
FH1	1/2	HY-80	Simple butt joint, manual arc welding	25 1/2	68	224	Cracked
FT1	1/2	Commercial high-strength heat-treated structural steel	Simple butt joint, manual arc welding	...	23 1/2	31	Cracked (Fig. 10)
F41	1/2	SAE 4340	Simple butt joint, inert-gas shield	11	29	180	Cracked
F43[c]	1/2	SAE 4340	Simple butt joint, manual arc welding	...	7–24	12–29	Cracked
F48	1/2	SAE 4340	Simple butt joint, manual arc welding	181 1/2	205 1/2	325 1/2	Cracked

[a] A straight groove (60-deg double vee) 6 in. long was cut longitudinally in the center of the specimen, 12 by 16 in.
[b] A circular groove, 4 in. diam was made in the center of a 12-in. diam circular plate.
[c] Since the power source failed at some time between 7 and 24 hr of testing, the effective testing time was between 12 and 29 hr.



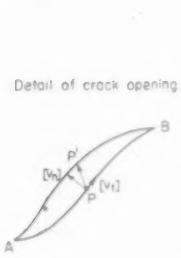


Fig. 11—Occurrence of a crack in a body containing residual stress

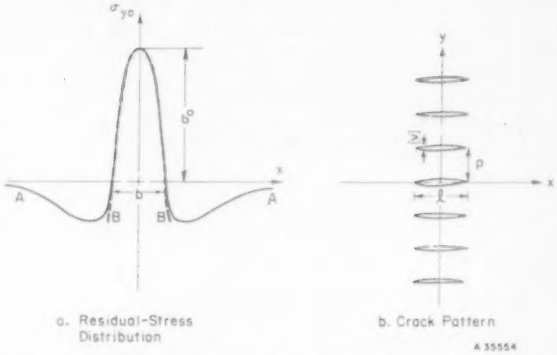


Fig. 12—Residual-stress distribution $0_{y0} = f(t)$ and crack pattern

Characteristics of Crack Patterns in SAE 4340 Weldments. Crack patterns produced in welded specimens by hydrogen charging can be classified under three types.

The first type is characterized by a series of short transverse cracks adjacent to a weld. This type of crack, which occurs in almost every weld, is a result of the longitudinal tensile residual stresses that are always present in the vicinity of a weld. In a simple butt joint or a bead-on-plate specimen, this type of crack is most predominant. In most cases, the crack pattern on one surface of a specimen is repeated on the other side. This shows that residual stresses of nearly the same magnitude are produced on both surfaces of a plate specimen.

Different crack patterns are found in the front and the back surfaces of fillet-welded tee-joints. Closely spaced, small transverse cracks are observed on the front surface. These cracks are generally composed of a series of closely spaced, shorter cracks and a series of more widely spaced, longer cracks. The series of closely spaced shorter cracks on the front surface does not appear on the back surface. Cracks observed on the back surface sometimes corresponded to the widely spaced, longer front-surface series. These results indicate that the series of closely spaced, shorter cracks in the front surface is produced by rather localized residual stress concentrated in the base metal along the edge of the weld. The series of widely spaced, longer cracks seem to be caused by longitudinal residual stresses, which are more evenly distributed on both surfaces.

The second type of crack is one caused by stress concentration. This type of crack generally has a parabolic form and penetrates into the base plate for a relatively long distance. The concentration of residual stress is produced either by an abrupt interruption of welding or by abrupt changes in a structural member.

The third type of crack pattern contains cracks caused by residual stresses transverse to a weld, and bending stress associated with angular distortion due to fillet welding. Typical of cracks caused by transverse stresses is the crack in the cross-butt weld specimen. The radial cracks at the center of the cutouts in Specimens B12 and B13 are believed to be caused by transverse stresses produced by the fillet welds on both sides of the cutout. The circular crack found in the circular-groove weld specimen is caused by radial tensile stress and is considered to belong to the third type of crack.

Secondary stress, associated with distortion, also may cause cracks. Longitudinal cracks observed in the back surface of a heavily welded fillet joint are believed to be caused by bending stresses in the bottom plate associated with the angular distortion due to fillet welding.

Effect of Mechanical Stress Relieving. Cracks were found in the as-welded specimen and specimens that had been mechanically stress relieved by stressing up to 60% of the yield stress; however, cracks were not found in the specimen that had been stressed to 80% of the yield stress. These results indicate that hydrogen-induced cracking is stress sensitive, and not plastic-strain sensitive, and that the crack pattern obtained as a result of hydrogen charging is produced by the existence of residual stresses.

Stress-Corrosion-Cracking Test

In specimens made with ABS Class B steel, cracks were observed in two of the five specimens tested. However, in specimens made with steels of higher strength level, cracks were observed in all specimens tested. As the strength level of the base plate increased, more cracking occurred in a shorter period of testing. A systematic crack pattern was obtained in the specimen made with the commercial high-strength heat-treated structural steel.

Analytical Investigation

Background and Objective

The Griffith theory has been widely accepted as a fundamental statement of the mechanism of fracture in a brittle material and has been applied by many researchers to various types of brittle fracture.[4] Irwin[5], Orowan[6], and many others have applied modifications of the theory to brittle fracture in structural steel. Petch and Stables[7] applied the theory to hydrogen-induced delayed fracture of metals. Masubuchi[8,9] also conducted an analytical study of the change of elastic-strain energy caused by the occurrence of a crack in a material containing residual stress.

These investigations suggest that an analytical study could be developed of the crack pattern produced in a weldment due to hydrogen charging.

General Theory of Crack Pattern

When a crack occurs in a material, new surface appears and the stress that existed around the crack is partly released. The strain energy stored in the material will decrease because of the formation of a crack, but additional energy is required to produce the new surface. If the decrease in strain energy is larger than the increase in surface energy, a crack may occur and the total energy of the body decreases because of the occurrence of the crack.

The increase of surface energy depends on the properties of the

material and is considered to be proportional to the surface area of the crack. If a crack of length l (between A and B in Fig. 11) occurs in a plate of uniform thickness, the increase of surface energy per unit plate thickness W_s is given by:

$$W_s = 2\rho l = 2\rho \int_A^B ds \qquad (1)$$

where

ρ = amount of energy required to produce a surface of unit area*

ds = line element, $ds = \sqrt{dx^2 + dy^2}$

The major characteristics of stress change due to cracking are:

1. The change of stress due to cracking can be considered as elastic, since this change releases stresses.
2. As the crack surface will remain free from stress after cracking, the normal and shearing stresses that were acting along the crack will be fully released.

Consequently, the decrease in elastic-strain energy per unit thickness due to the occurrence of a crack, W_e, is given as:†

$$W_e = \int_A^B {}^1/_2 [\sigma_n[v_n] + \tau[v_t]] ds \qquad (2)$$

where

σ_n, τ = normal and shearing stresses, respectively, that were acting along the crack

$[v_n], [v_t]$ = relative displacements of both sides of the crack in the normal and tangential directions, respectively.

The decrease of total energy of the system, U, is:

$$U = W_e - W_s \qquad (3)$$

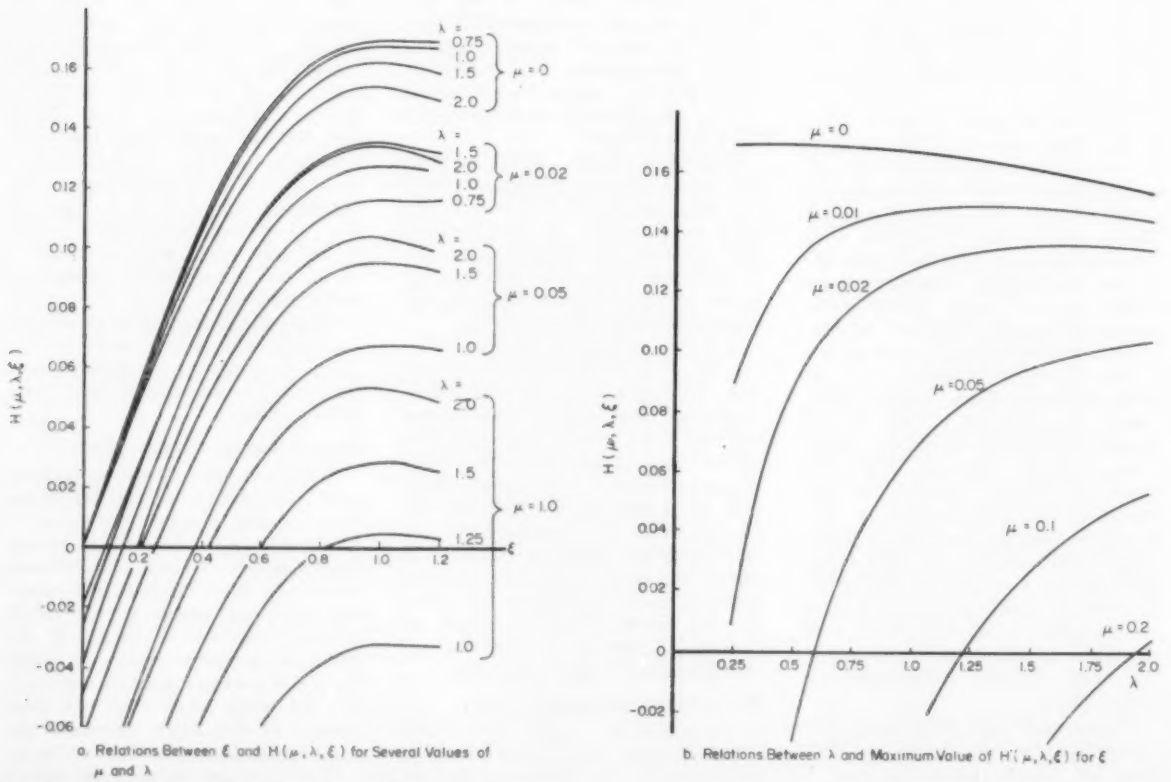
Since the strain change encountered when the crack occurs is elastic, the relative displacement $[v_n], [v_t]$ in eq. 2 can be calculated from the stress distribution σ_n, τ. Consequently, the decrease in total energy, U, can be calculated when the path of a crack and the distribution of residual stress along the crack are determined.

The discussion so far has been based on a single crack between A and B. However, the above equation can be applied to a system of cracks without any basic change. When the crack pattern is changed, a different value of U is obtained. Some crack patterns will produce a large value of U, and others will produce a low value of U. The crack pattern that produces the largest energy is more likely to occur than the other patterns. Thus, the crack pattern can be determined theoretically as a function of stress distribution and the material constant, ρ.

The above analysis, unfortunately, shows that the distribution of residual stress, in general, cannot be determined from the crack pattern. The unique solution of stress distribution cannot be determined from knowledge of the crack pattern because of indeterminate coefficients associated with

* The value of ρ may be mostly plastic work, as has been pointed out by Felbeck and Orowan.[18]

† As the value of crack opening in the tangential direction, $[v_t]$, is expected to be much smaller than that in the normal direction, $[v_n]$, the second term in eq. 2 can be neglected except where an end of the crack reaches to the free end of the body. In that case, the value of $[v_t]$ may become a large value, as shown in the sketch below:



a. Relations Between ξ and $H(\mu, \lambda, \xi)$ for Several Values of μ and λ

b. Relations Between λ and Maximum Value of $H(\mu, \lambda, \xi)$ for ξ

Fig. 13—Analysis for parabolic stress distribution

the integration of the unknown function. In order to determine the stress distribution from the crack pattern, several assumptions and approximations must be made, except in a very simple stress system.

Mathematical Analysis of Crack Pattern in Simple Stress Fields

Part I. Infinite Plate With Residual Stress Varying in One Direction. If the residual stress $\sigma_{yo} = f(x)$, which varies along the x-direction but is uniform in the y-direction, is present in an infinite plate, a series of parallel cracks of equal length, l, and equal pitch, p, will be produced, as shown in Fig. 12. Such a residual-stress distribution and crack pattern are typical of a simple butt joint.

1. *Fundamental Equations.* Suppose that an arbitrary stress distribution $\sigma_{yo} = f(x)$, as shown by curve AA in Fig. 12, is expressed by:

$$\sigma_{yo} = f(x) = \frac{E}{2l} \sum_{n=1}^{\infty} nB_n \frac{\sin n\theta}{\sin \theta} \quad (4)$$

where

E = Young's modulus
l = length of crack
θ = parameter which expresses the position x, $\cos \theta = \dfrac{x}{l}$

B_n = coefficient =

$$\frac{4l}{\pi E} \quad \frac{1}{n} \int_0^{\pi} \sigma_{yo} \sin n\theta \cdot \sin \theta \cdot d\theta$$

The opening of each crack, $[v]$, is given by:

$$[v] = \sum_{n=1}^{\infty} A_n \sin n\theta \quad (5)$$

The relation between the two coefficients A_n and B_n is as follows:

$$A_n = \sum_{j=1}^{\infty} \gamma_{nj} B_j \quad (6)$$

where γ_{nj} is an inverse matrix of matrix β_{nj}:

$$\beta_{nj} = \alpha_{nj} + \delta_{nj} \quad (6')$$

$$\alpha_{nj} = \left(\frac{2}{\pi}\right)^2 \left(\frac{j}{n}\right) \int_0^{\pi} \sin\theta \cdot \sin n\theta \cdot d\theta \int_0^{\pi} \cos j\theta' (\cos\theta' - \cos\theta) \left[\sum_{m=1}^{\infty} \frac{(\cos\theta' - \cos\theta)^2 + 3m^2\lambda^2}{\{(\cos\theta' - \cos\theta)^2 + m^2\lambda^2\}^2} \right] d\theta \quad (6'')$$

$$\lambda = \frac{p}{l}$$

$$\delta_{nj} = \begin{cases} 1 (n = j) \\ 0 (n \neq j) \end{cases}$$

The strain energy released by the occurrence of each one of the parallel cracks, W_{e1} (for unit thickness) is given by:

$$W_{e1} = \frac{E}{8} \cdot \frac{\pi}{2} \left(\sum_{n=1}^{\infty} \sum_{j=1}^{\infty} n\gamma_{nj} B_n B_j \right) \quad (7)$$

The decrease in total energy caused by the occurrence of each crack, U_1, is given by:

$$U_1 = W_{e1} - 2\rho l \quad (8)$$

The mean decrease in total energy in the y-direction, U, is given by:

$$U = \frac{1}{p} U_1 \quad (9)$$

The combination of l and p that gives the maximum value of U determines the crack pattern.

2. Analysis for Parabolic Stress Distribution. A numerical analysis of crack pattern was made on a simple, mathematically expressed stress distribution which simulates the distribution of residual stress in the vicinity of a simple butt weld. This was done considering the following facts:

(a) The most predominant cracks observed in the hydrogen-induced-cracking tests of weldments are short transverse cracks in the region near the weld.

(b) The above analysis shows the residual stresses that are responsible for cracking are those which were acting along the length of the cracks (σ_{yo}) in the range of $|x| \leqq l/2$, and residual stresses which existed in the region outside the cracks have no influence on energy decrease due to cracking.

A parabolic stress distribution as expressed by eq 10 and Curve BB in Fig. 12a is used for the analysis:

$$\sigma_{yo} = \sigma_0 \left\{1 - \left(\frac{2x}{b}\right)^2\right\} \quad (10)$$

where

σ_0 = maximum tensile stress at the weld center
b = width of the tension zone

The parabolic stress distribution can be used as an approximate residual-stress distribution in the vicinity of the weld. The analysis was made in the range $|2x/b \leqq 1.2$.

The coefficient B_n for this stress distribution is in eqs. 11:

$$\left.\begin{aligned} B_1 &= \left\{1 - \frac{1}{4}\left(\frac{l}{b}\right)^2\right\} \left(\frac{\sigma_0}{E}\right) 2l \\ B_3 &= -\frac{1}{12}\left(\frac{l}{b}\right)^2 \left(\frac{\sigma_0}{E}\right) 2l \\ B_2 &= B_4 = B_5 = B_6 = \cdots = 0 \end{aligned}\right\} \quad (11)$$

U_1 and U are given by:

$$\left.\begin{aligned} U_1 &= \frac{\pi}{4}\left(\frac{\sigma_0}{E}\right)(\sigma_0 b^2) F_1(\mu, \xi) \\ U &= \frac{\pi}{4}\left(\frac{\sigma_0}{E}\right)(\sigma_0 b) H(\mu, \lambda, \xi) \end{aligned}\right\} \quad (12)$$

where

$$\xi = \frac{l}{b} \quad (12')$$

$$\left.\begin{aligned} F(\mu, \xi) &= \xi^2 g(\xi) - 2\mu\xi \\ H(\mu, \lambda, \xi) &= \frac{1}{\lambda}\{\xi g(\xi) - 2\mu\} \end{aligned}\right\} \quad (12'')$$

$$g(\xi) = \gamma_{11} - \frac{1}{2}\left(\gamma_{11} + \frac{\gamma_{12}}{3}\right)\xi^2 + \frac{1}{8}\left(\frac{\gamma_{11}}{2} + \frac{\gamma_{12}}{3} + \frac{\gamma_{22}}{6}\right)\xi^4 \quad (12''')$$

In the above equation, the resistance of the material against crack extension is expressed by the dimensionless parameter μ, where μ is the ratio of critical crack length of the material for the stress level σ_0, l_{cr_0} to the width of the tension zone:

$$\left.\begin{aligned} l_{cr} &= \frac{4}{\pi}\frac{E \cdot \rho}{\sigma_0^2} \\ \mu &= \frac{l_{cr}}{b} \end{aligned}\right\} \quad (13)$$

Equation 12 indicates that a dimensionless function $H(\mu, \lambda, \xi)$ determines the crack pattern.

The results of numerical computation of $H(\mu, \lambda, \xi)$ are shown in Fig. 13. Figure 13a shows the relations between ξ and $H(\mu, \lambda, \xi)$ for several combinations of μ and λ. In almost all cases the maximum value of H occurs around $\xi = 1.0$. This indicates that length of the most stable crack is approximately the same as the width of the tension zone.

Relations between λ and the maximum value of H for ξ are shown in Fig. 13b for several values of μ. The combination of ξ and λ which gives the maximum value of H can be obtained for a given value of μ; thus, the most stable crack pattern for a given material and stress distribution is determined.

The maximum value of H occurs at $\lambda = 1.0 \sim 1.25$ for $\mu = 0.01$; and $\lambda = 1.5 \sim 1.75$ for $\mu = 0.02$. When μ increases the value of λ which gives the maximum value of H increases; in other words when the material becomes less brittle the interval between cracks increases. The value of H itself also decreases as μ increases, and it becomes negative when the value of μ becomes larger than a certain critical value; in other words, a stable crack will not occur due to

residual stress when the material has higher toughness than some critical value. The critical value can be determined as follows.

The largest amount of strain-energy release due to each crack is obtained when only one crack is produced. In the case of a single crack, the analysis becomes very simple:

$$\alpha_{nj} = 0$$

$$\gamma_{nj} = \delta_{nj} = \begin{cases} 1 & n = j \\ 0 & (n \neq j) \end{cases} \quad (14)$$

Function F, which determines the decrease in total energy U_1, is:*

$$F = \left(\xi^2 - \frac{1}{2}\,\xi^4 + \frac{1}{12}\,\xi^6\right) - 2\mu\xi \quad (15)$$

If the value of μ is larger than 0.29, the value of F is not positive at any value of ξ (in the range $\xi = 0 \sim 1.2$), so even a single crack will not occur.

Part II. Stability of Circular Cracks in Radially Symmetric Stress Field. A mathematical analysis of crack pattern has been made also for a circular crack in a radially symmetric stress field. The distribution of residual stress is assumed as follows:

$$\left.\begin{aligned} \sigma_r = \sigma_\theta = \sigma_0 \\ r \leq b \end{aligned}\right\}$$
$$\left.\begin{aligned} \sigma_r = -\sigma_\theta = \sigma_0 \left(\frac{b}{r}\right)^2 \\ r > b \end{aligned}\right\} \quad (16)$$

where, σ_r and σ_θ are components of radial and circumferential stresses, respectively. Residual stresses of nearly the same distribution as given in the above will be produced in a spot-welded joint or in a centrally heated circular plate.[11] The residual-stress distribution in a circular-groove weld is probably only a little different from that shown in eq 16.

When a circular crack of radius r occurs, the decrease in total energy, U, is:

$$\left.\begin{aligned} U = \frac{2\pi}{E}\, r^2\sigma_0^2 - 4\pi r\rho \\ r \leq b \end{aligned}\right\}$$
$$\left.\begin{aligned} = \frac{2\pi\, b^4}{E\, r^2}\,\sigma_0^2 - 4\pi r\rho \\ r > b \end{aligned}\right\} \quad (17)$$

The value of U becomes maximum at $r = b$; in other words a crack is most likely to occur at the outer edge of the highly stressed area. No circular crack will occur when the value of σ_0 is smaller than $\sqrt{2E\rho/b}$.

* $\overline{U_1}$, instead of $\overline{U}$, must be considered in this case. The value of U is zero for the case of a single crack.

Discussions of Analytical Investigation

Through the analytical investigation, it has been found that the crack pattern that is most likely to occur is theoretically determinate when the residual-stress distribution and the properties of the material are known.

A mathematical analysis has been made of the crack pattern in a simple stress field which simulates the residual stress in a butt joint. The following results have been obtained:

1. A series of cracks will be produced when the critical crack length of the material at the yield stress level is smaller than approximately 0.02 times the width of the zone where tensile residual stresses exist.
2. The length of serial cracks is approximately the same as the width of the tension zone.
3. No crack will be produced when the critical crack length of the material is larger than about 0.29 times the width of the tension zone.

These results indicate the limitation of the properties of the material to be used in the hydrogen-induced-cracking test. The critical crack length of the material before hydrogen charging must be larger than 0.29 times of the tension zone; otherwise a crack may occur during or after welding. The critical crack length after charging must be less than 0.02 times the width of the tension zone, otherwise a series of cracks will not occur due to hydrogen charging.

However, the analytical investigation has shown that it is not possible, in general, to determine the exact distribution of residual stress from crack-pattern information. This makes it difficult to evaluate the various crack patterns which have been observed in the experiments. It would be desirable to have a method of evaluating residual stress distribution when only the crack pattern was known. A quantitative method could be developed as follows.

The analytical investigation has shown that there is one crack pattern for a given stress distribution and a given material. If an external load is applied during hydrogen charging, the crack pattern will be changed. Perhaps the length of crack will increase as the applied stress increases, and at some critical stress the specimen will fracture completely. This critical value of applied stress may vary as the residual-stress distribution or joint design varies, and should be related to the highest applied stress which the structure can support for given conditions of residual-stress distribution and material properties. It might be possible to use this critical-stress value to evaluate the residual-stress distribution.

Conclusions

It was found that a systematic crack pattern could be produced in a weldment made with SAE 4340 steel heat treated to a high strength by charging the weldment with hydrogen. Different crack patterns which could be related to the residual-stress distribution were obtained when different type specimens were tested. It also was found that cracking due to hydrogen charging was stress sensitive, rather than plastic-strain sensitive. Summarizing these findings, it can be concluded that the hydrogen-induced-cracking technique can be used as a method to study the residual-stress distribution in a complex weldment.

Crack patterns also were obtained with the stress-corrosion cracking test of weldments made with several types of steel.

Analytical investigations of crack patterns have been made. Mathematical equations to express the relation between the residual-stress distribution and the crack pattern have been developed.

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An Investigation of the Low-Temperature Impact Properties of Stainless-Steel Weldments

The effects of three processes on Charpy V-notch impact properties are discussed—covered electrode welding, the gas metal-arc process and submerged-arc welding

BY H. W. MISHLER AND H. J. NICHOLS

ABSTRACT. The Charpy V-notch impact properties were determined for weld joints made in 3 in. thick AISI Types 304, 304L and 310 stainless steels. These properties were obtained at the temperatures of liquid nitrogen (−320° F) and liquid hydrogen (−421° F). To study the effects of the welding process used, the weld joints were made by four different methods: covered electrode, gas metal-arc, submerged-arc heavy pass and submerged-arc light pass. The impact specimens were machined from the joints so that the notches were located in either the unaffected base plate, the heat-affected zone or the weld metal. The notches in the heat-affected zones were located at controlled distances from the fusion line.

The results of this study indicated that the best weld-metal impact properties were achieved in the gas metal-arc weld joint in the Type 304L steel; that the best heat-affected-zone impact properties were achieved in the Type 310 steel; and that the impact properties of the Types 304 and 310 unaffected base metal were about the same and were superior to those of the 304L base metal. However, the impact properties of the Type 304L weld joints showed the least variation from one zone to another across the joint.

Introduction

To select a constructional material for cryogenic storage vessels, the mechanical properties of the material at such temperatures must be known. Three steels that might be used for such applications are AISI Types 304, 304L and 310. A cooperative program to determine the notch-bar impact properties of weld joints in the three steels at the temperatures of −320° F (liquid nitrogen) and −421°F (liquid hydrogen) has been conducted by the United States Steel Corp. and by Battelle Memorial Institute. Several welding processes could be used to weld thick material that would be used to construct a storage vessel. It was not known whether the impact properties of the weld joint would be affected by the type of welding used. Thus, welds were prepared by each of three processes: manual covered-electrode welding, automatic gas metal-arc welding, and automatic submerged-arc welding (both heavy and light passes).

Materials and Procedures

The base material used in this study was AISI Type 304, 304L and 310 steel in the form of plate approximately 3 in. thick. The composition of this material is given in Table 1.

The filler materials used in the preparation of the weld joints were those that would be normally applied in commercial practice. Covered electrodes and filler wires of AISI Type 308 and 308L composition were used for welding the Types 304 and 304L steels, respectively. The Type 310 steel was welded with AISI Type 310 electrodes. The compositions of the filler materials also are noted in Table 1.

Welding Procedures

Four methods were used to weld these materials: manual covered electrode, automatic gas metal-arc, automatic submerged-arc heavy pass and automatic submerged-arc light pass. These procedures were intended to simulate those used commercially. Both light and heavy passes were deposited by the

Table 1—Chemical Compositions of Base-Plate and Filler Materials

AISI material	Chemical Composition, %									
	C	Mn	P	S	Ni	Cr	Si	Cu	Mo	Other
Base plate[a]										
304 (heat X22584)	0.055	1.55	0.026	0.028	10.0	18.4	0.60	0.32	0.38	0.018 Ti
304-L (heat X20635)	0.018	1.17	0.018	0.024	9.96	19.5	0.63	0.072	0.15	0.016 Ti
310 (heat X46420)	0.054	1.00	0.019	0.018	19.1	24.0	0.44	0.28	0.12	0.007 Ti
	Filler-metal analysis[b]									
308 covered electrode	0.05	1.82	0.018	0.006	9.96	20.8	0.30	0.16	0.18	0.06 Co
308 wire	0.04	1.74	0.022	0.011	9.83	21.3	0.30	0.18	...	0.06 Co
308-L covered electrode	0.029	1.60	0.022	0.015	9.80	20.32	0.37	0.07	0.05	0.029 N
308-L wire	0.025	1.95	0.011	0.019	9.81	20.25	0.40	0.09	...	0.02 Co
310 covered electrode	0.09	1.64	0.010	0.006	21.16	27.90	0.34	...	...	...
310 wire	0.12	1.83	0.011	...	21.96	27.11	0.33	...	0.02	0.012 Co

[a] Composition furnished by United States Steel Corp.
[b] Composition furnished by electrode supplier.

H. W. MISHLER is Welding Engineer at Battelle Memorial Institute, Columbus, Ohio, and H. J. NICHOLS is Chief Research Engineer, Metals-Joining, U. S. Steel Corp., Applied Research Laboratory, Monroeville, Pa.

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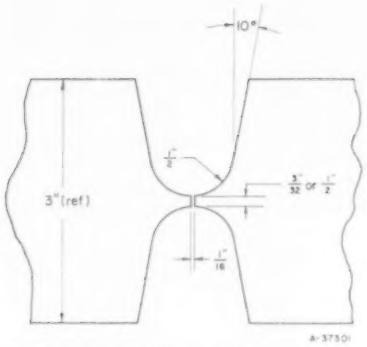


Fig. 1—Design of weld joint

Table 2—Welding Conditions

Welding process	Welding current, amp	Welding voltage, vs	Polarity	Travel speed, ipm	Number of passes	Pass thickness, in.	Electrode of wire diameter, in.
Covered electrode	170–185[a]	20–23	Reverse	12	70	1/8	5/32
Gas metal-arc	410–430	26–29	Reverse	18	55	1/8	3/32
Submerged-arc, light pass	390–400	28–30	Reverse	16	50	1/8	5/32
Submerged-arc, heavy pass	530–550	35–38	Reverse	5	17	0.3	3/32

[a] Welding current was adjusted during welding by a foot control.

submerged-arc process to determine whether the size of the pass would affect the impact properties of the weld joint.

The welding conditions used in this study are given in Table 2. The shielding gas, where used, was argon flowing at 75 cfh. The pass thickness was the same (1/8 in.) for the manual covered electrode and the gas metal-arc welds. Fewer passes were required in the gas metal-arc weld, though, since these passes were wider than were the covered-electrode passes. A standard stainless-steel flux was used for the submerged-arc welding of the three steels.

The joint geometry used in this study is shown in Fig. 1. After the joints were machined and prior to any welding operations, the base material was cleaned with acetone to remove oil, dirt and layout fluid. Two root passes were deposited by the gas tungsten-arc process with bare filler wire of the appropriate composition for the steel being welded. When heavy passes were made by the submerged-arc process, the land was increased to 1/2 in. and the root passes were made by submerged-arc welding. After a weld joint was completed, it was cut out of the weldment. The edges of the base material then were remachined to the same geometry, and the next weld of the series was deposited.

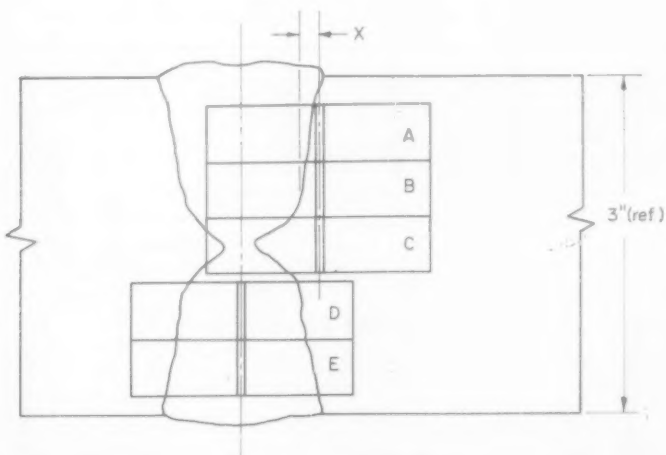
Since the product for which these steels are intended would be very massive, the weld joints would cool to room temperature between passes. Such an interpass temperature was used in making all welds. No means of accelerated cooling was applied.

The welds were approximately 6 in. long and were started and stopped on runoff tabs cut from the base material. The welds were cleaned by hand wire brushing after each pass, and slag was removed with a chipping hammer. Grinding was used, where necessary, to remove any entrapped slag.

The welds were inspected after each layer of weld passes by means of dye penetrant. Radiographs also were made of each weld when the thickness of the deposited weld metal reached 1 and 2 in. Cracking occurred in the Type 310 weld metal deposited by the gas metal-arc and submerged-arc processes. The results of these inspections were that all other weld joints appeared sound.

Chemical analyses were made of the various weld joints. Except for the submerged-arc welds, all of the weld metals had compositions that differed only slightly from those of the filler wire or electrode. The submerged-arc welds, however, had a much higher silicon content than did the filler wire or base material, as is shown in Table 3. The silicon was picked up from the flux that was used in welding the Types 304 and 304L steels. A weld metal with a high silicon-carbon ratio such as was encountered in these welds may be susceptible to intergranular fissuring. Side bend tests made of the submerged-arc weld joints disclosed that fissuring had, in fact occurred. A photomacrograph of

Fig. 2—Side-bend specimen of submerged-arc weld joint in AISI 304 steel showing fissures in weld metal



"X" indicates the distance from the notch center line to the fusion line

Fig. 3—End view of weld joint showing location of impact specimens

Table 3—AISI Type 308 and 308-L Weld-Metal Chemical Analysis

Filler wire	Welding method	Flux type	Chemical composition, % C	Ni	Cr	Mn	Si	N
Type 308	Covered electrode	...	0.06	9.81	20.0	1.51	0.51	0.058
Type 308	Gas metal-arc	...	0.04	9.82	21.1	1.52	0.27	0.18
Type 308	Submerged arc	Modified	0.06	9.4	18.8	17.5	0.69	0.09
Type 308-L	Gas metal-arc	...	0.02	9.86	19.82	1.79	0.45	...
Type 308-L	Submerged arc	Standard	0.03	9.80	19.96	1.80	0.92	...
Type 308-L	Submerged arc	Modified	0.03	10.0	18.7	1.97	0.86	...

one of these specimens is shown in Fig. 2. Additional submerged-arc welds were made using a modified flux in an attempt to reduce the silicon content of the weld metal. Chemical analyses of these additional welds indicated that a high silicon content still was being obtained, although it was slightly lower than that previously obtained. Bend tests showed that fissures still were present. The impact tests that will be reported later were conducted on the submerged-arc weld joints that were made using a standard commercial flux.

The covered-electrode welds in the Type 310 steel were sound. However, the welds made by the other techniques cracked longitudinally. On a Shaeffler diagram, the Type 310 filler-wire and base-plate compositions fell within the austenitic region. Cracking probably was due to a lack of ferrite in the weld metal. No notch-bar impact tests were made of the gas metal-arc or submerged-arc welds in the Type 310 steel.

Notch-Bar Impact-Testing Procedures

Notch-bar impact tests were made of the weld metal, the weld heat-affected zone and the unaffected base plate. Charpy V-notch impact specimens were cut from the weld joint so that the notch was located in the weld metal and also in the heat-affected zone at various distances from the fusion line. Figure 3 shows the orientation of the impact specimens. Dimension X varied from $^1/_{16}$ to $^1/_2$ in., depending on the location of the bar. Specimens A, B and C were used to obtain the impact properties of the heat-affected zone, and Specimens D and E were used to obtain the impact properties of the weld metal. About 1 in. was discarded from each end of the weld joint so that the specimens would be cut from the central portion of the 6 in. long joint. The last welds to be made were the heavy-pass submerged-arc welds. When the previous welds were cut out, a certain amount of base material necessarily was removed. By the time the last welds were made, the base material was too narrow to obtain specimens with the notch located $^1/_2$ in. from the fusion line.

Impact tests were conducted at −320° F and −421° F. The specimens were wrapped in paper for immersion in the coolant and transfer to the impact machine. The paper retained some of the liquid coolant around the specimens during transfer to the impact machine, and also served as an insulating layer. The specimens that were broken at −320° F were cooled in liquid nitrogen for 5 min. The specimens that were broken at −421° F were precooled in liquid nitrogen for at least 2 min, then transferred to the liquid hydrogen for 1 min, and finally transferred to the impact machine. The total transfer time from the liquid hydrogen to the impact machine to the instant of fracturing was 5 to 6 sec. Under these conditions, notch-bar impact data are obtained

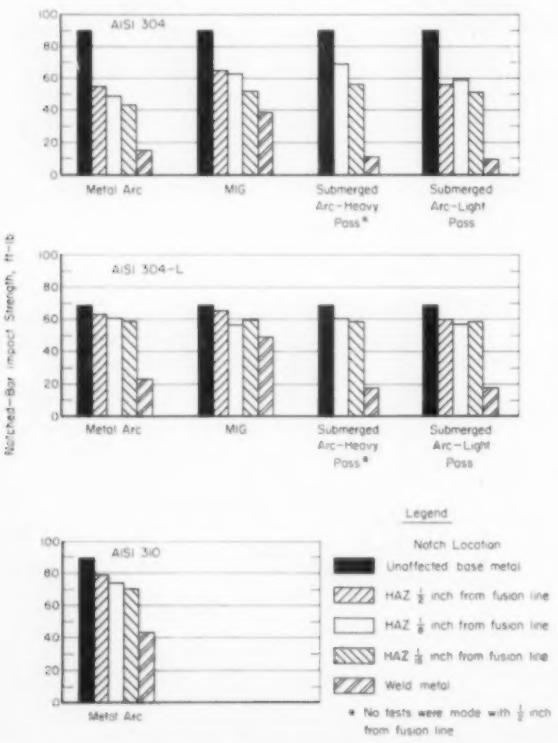


Fig. 4—Notched-bar impact strengths at −320° F

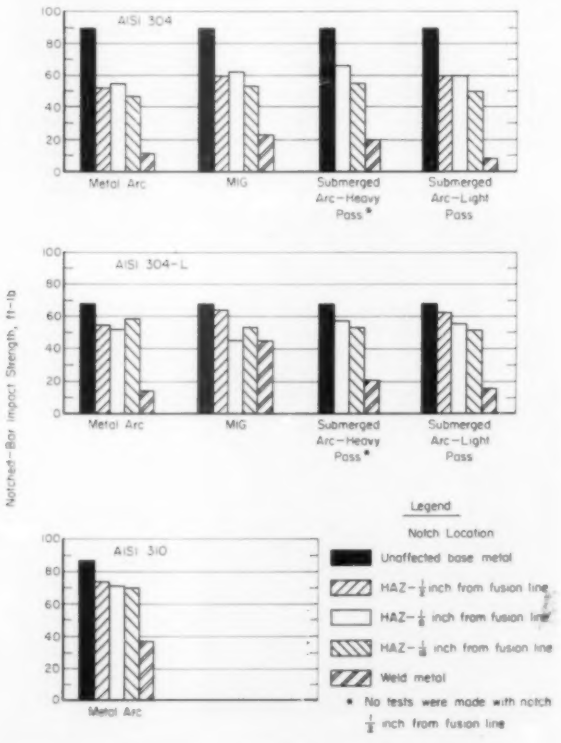


Fig. 5—Notched-bar impact strengths at −421° F

Table 4—Notch-bar Impact Properties of Base Metals

Material	Impact energy,[a] ft-lb −320° F	−421° F
AISI 304	90	87
AISI 304-L	68.5	67.5
AISI 310	88	86

[a] These values are averages of three tests.

without the complication of a significant temperature rise.

Results and Discussion

The results of the notch-bar impact tests of the unaffected base metal are given in Table 4. The impact properties of the weld joints themselves are given in Tables 5 and 6, respectively, for the test temperatures of −320° F and −421° F. In addition, the results are presented graphically in Figs. 4 and 5. These results are summarized as follows:

1. The notch-bar impact properties of the unaffected base metal were better than either those of the heat-affected zone or of the weld metal for all three steels.

2. The best weld-metal notch-bar impact properties at each test temperature were achieved by the 308L weld metal deposited by the gas metal-arc process.

3. The best heat-affected-zone notch-bar impact properties at each test temperature were achieved by the Type 310 steel.

4. The Type 310 manual covered electrode weld metals had much higher notch-bar impact properties than did the Type 304 or 304L covered electrode weld metals.

5. The notch-bar impact properties of the gas metal-arc weld metals were superior to those made by manual covered electrode or submerged-arc welding.

6. The notch-bar impact properties of the heat-affected zone in Type 304 steel were influenced by the number of passes deposited in the weld joint. The best notch-bar impact properties were achieved when the fewest passes were used.

7. Notch-bar impact properties of the heat-affected zone were much higher than those of the weld metal for all weld joints.

8. The notch-bar impact properties of the heat-affected zone generally increased as the distance of the notch from the fusion line increased.

9. The difference in impact properties between the unaffected base metal and the heat-affected zone was greater for the Type 304 steel than for the other two steels. Thus, the adverse effect of welding on the impact properties of the steel was greatest for the Type 304 steel.

The notch-bar impact properties of the Types 308 and 308L weld metals (deposited respectively in Type 304 and 304L steels) definitely are affected by the welding process and procedure used. Weld metals with the highest notch-bar impact properties are produced by the gas metal-arc process. The weld metals produced by manual covered electrode and submerged-arc welding, with one exception, had lower notch-bar impact properties. The submerged-arc heavy-pass weld metal in Type 304 steel had notch-bar properties that were almost the same as those for the gas metal-arc weld at −421° F. The difference in weld-metal notch-bar properties resulting from the use of different welding methods may be attributable to the cleanliness of the weld metals deposited. Photomicrographs of Type 308L weld metals produced by each of the four welding procedures are shown in Fig. 6. The gas metal-arc weld metal had fewer and generally smaller inclusions than the weld metals produced by the other methods. The fissures that occurred in the submerged-arc welds also probably reduced the notch-bar properties of these weld metals.

The notch-bar impact strengths of the weld metals are considerably lower than those of the heat-affected zones. The chief reason for this difference is felt to be due to the coarser grain structure of the weld metal, the presence of weld-metal inclusions, and, in some cases, the presence of microfissures. Although, it has been stated that a high level of interstitial elements can affect the impact properties at these temperature levels, plus nitrogen contents of the Type 308 weld metals are rather close together,

Table 5—Results of Impact Tests at −320° F on Vee-notched Charpy Specimens

Steel type	Welding method	Impact energy,[a] ft-lb: Notch in Weld metal	Notch in heat-affected zone at indicated distance from notch to fusion line, in. 1/16	1/8	1/2
AISI 304	Manual covered electrode	15	44	49	55
	Gas metal-arc	38.5	51.5	63	64.5
	Submerged arc, heavy pass	12	56	68	—[b]
	Submerged arc, light pass	10	51	59	57
AISI 304-L	Manual covered electrode	23	58	60.5	63.5
	Gas metal-arc	48.5	58.5	56	65.5
	Submerged arc, heavy pass	17.5	58.5	60	—[b]
	Submerged arc, light pass	18	59	57.5	60
AISI 310	Manual covered electrode	43	71	74	79.5

[a] These values are averages of three tests for the weld metal, four tests for the notch located 15/16 and 1/8 in. from the fusion line, and two tests for the notch located 1/2 in. from the fusion line.

[b] The base plate was too narrow to machine specimens with the notch located 1/2 in. from the fusion line.

Table 6—Results of Impact Tests at −21° F on Vee-notched Charpy Specimens

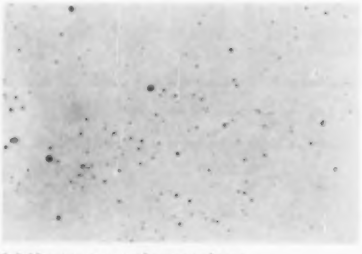
Steel type	Welding method	Impact energy,[a] ft-lb: Notch in weld metal	Notch in heat-affected zone at indicated distance from notch to fusion line, in. 1/16	1/8	1/2
AISI 304	Manual covered electrode	12	47	55	52.5
	Gas metal-arc	22.5	53	62	60
	Submerged arc, heavy pass	20	55.5	66	—[b]
	Submerged arc, light pass	8	50	60	60
AISI 304-LC	Manual covered electrode	14	59	52	55
	Gas metal-arc	45	53	45	64
	Submerged arc, heavy pass	21	53	57.5	—[b]
	Submerged arc, light pass	16	52	56	62.5
AISI 310	Manual covered electrode	37	70.5	71	73.5

[a] These values are averages of three tests for the weld metal, four tests for the notch located 1/16 and 1/8 in. from the fusion line, and two tests for the notch located 1/2 in. from the fusion line.

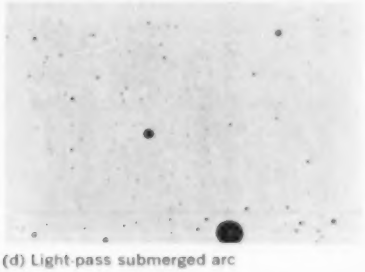
[b] The base plate was too narrow to machine specimens with the notch located 1/2 in. from the fusion line.

(a) Covered electrode

(b) Gas metal-arc



(c) Heavy-pass submerged arc



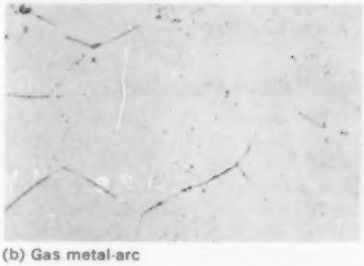
(d) Light-pass submerged arc

Fig. 6—AISI 308 weld metals deposited by various welding processes. X 500. (Reduced 53% on reproduction)

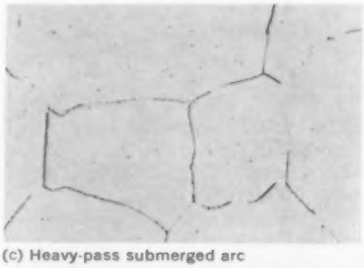
yet the difference in impact energies is quite large (12 to 38.5 ft-lb). Thus, it is felt that interstitial elements have had only a small effect on the notch-bar impact properties of the weld metals.

The notch-bar properties of the heat-affected zone of the Type 304 steel appear to be influenced slightly by the welding method. The welding process, itself, would not affect these properties. Instead, they would be influenced by the welding conditions used. Heat-affected zones with the lowest notch-bar properties are associated with the weld joints made by manual covered electrode welding. In this process, the heat input is quite low. In contrast, the heat-affected zones of the weld joints in which the heat input was higher had higher notch-bar properties. Variations in the heat-affected zone notch bar properties were more pronounced at the higher test temperature (−320° F). At this temperature, this effect is not noticed in the heat-affected zones of the Type 304L steel. Such behavior seems to indicate that precipitation of a carbide in the grain boundaries of the Type 304 steel may have occurred. Photomicrographs of the various heat-affected zones in Fig. 7 show that precipitation indeed has occurred in the grain boundaries. It appears that in the heat-affected zones associated with the higher heat inputs a greater amount of intergranular precipitation of the carbides has occurred. This apparently heavier precipitate may simply be an agglomeration of a fine precipitate, a precipitate too fine to be detected by the microscope. Such a situation could be caused by the differences in heat inputs in the different welding processes. In the covered electrode welds, a low heat input was used, thus the heat-affected zone would be relatively narrow. The temperature at a point a given distance from the fusion line would be lower than if a higher heat input were used. As the heat input was increased in the other processes, the heat-affected zone would become wider and the temperature of the given point just mentioned would be increased. Thus, at a given distance from the fusion line in the covered electrode weld heat-affected zone, the fine low-temperature precipitate may be present. The precipitate that is present in the higher heat input heat-affected zones at the same point is a higher temperature precipitate. The fine, low-temperature precipitate may be more damaging to the impact properties of the heat-affected zone in that it is a more continuous network of precipitate. The heavier, higher temperature precipitate appearing in the photomicrographs may not be as continuous as the fine precipitate, and thus may not be as damaging to the impact properties. This situation would explain why the impact properties increase as the apparent amount of precipitate also increases. At the lower test temperature, the variation in notch-bar properties of the Type 304 heat-affected zone is not so great as at the higher test temperature, although the trend is similar. Here again, the impact properties of the high heat input heat-affected zone are better than the impact properties of the low heat input heat-affected zone. The formation of this intergranular precipitate probably also is the cause for the relatively large difference in impact properties between the Type 304 base material and heat-affected zone. The types 304L and 310 retain their base-metal impact properties to a greater degree when welded.

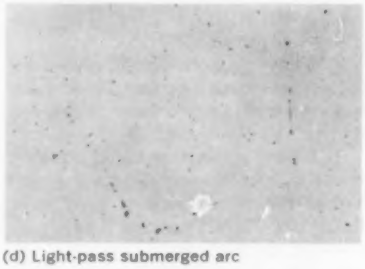
(a) Covered electrode



(b) Gas metal-arc



(c) Heavy-pass submerged arc

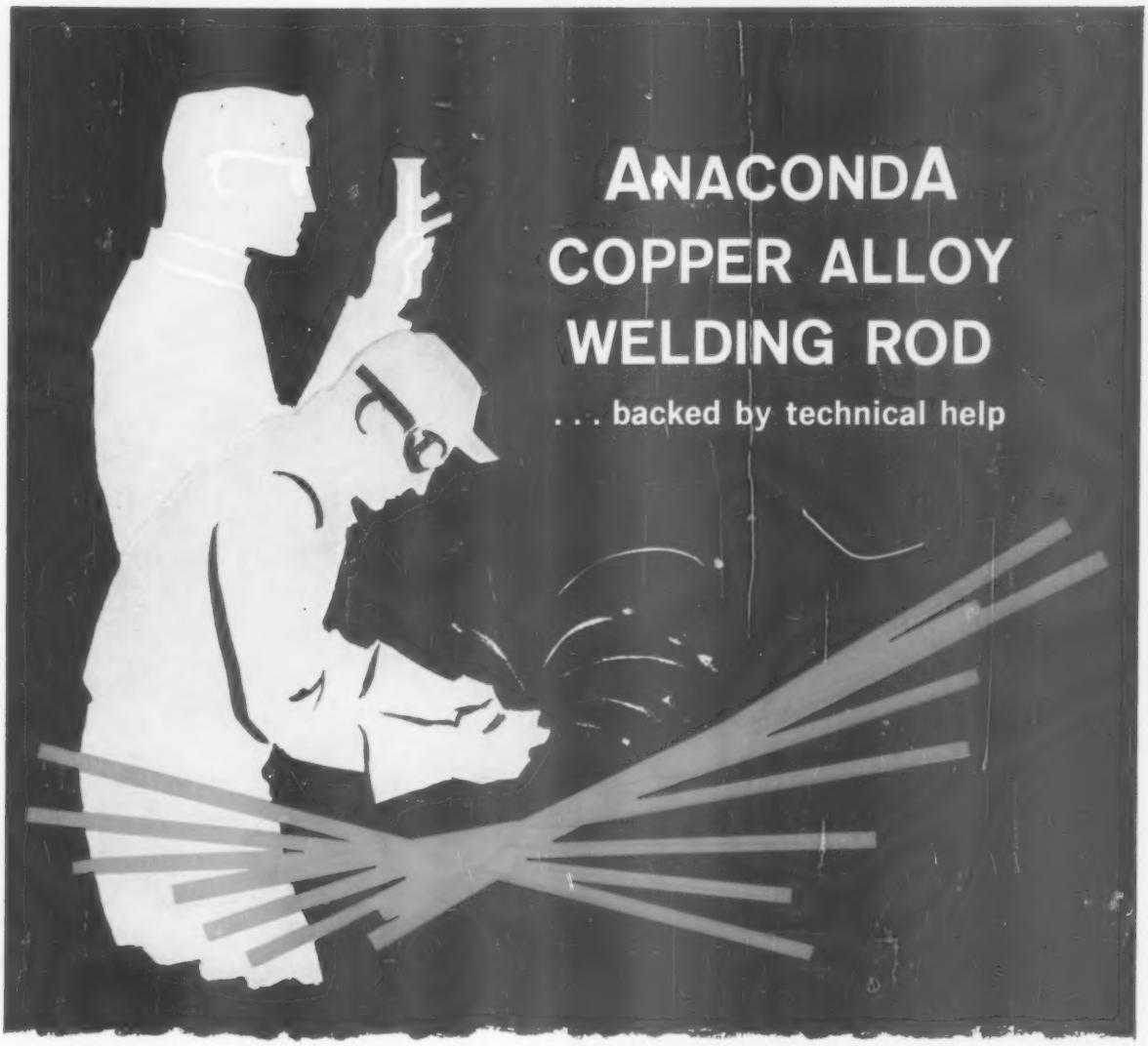


(d) Light-pass submerged arc

Fig. 7—Heat-affected zones in AISI 304 steel. 10% oxalic acid electrolytic etchant. X 500. (Reduced 53% on reproduction)

Acknowledgment

The authors appreciate the assistance in the planning and conducting of this work given by P. J. Rieppel, R. E. Monroe and J. E. Campbell, of Battelle Memorial Institute, and R. R. Brady, of Lee Wilson Engineering Co., Cleveland, Ohio.



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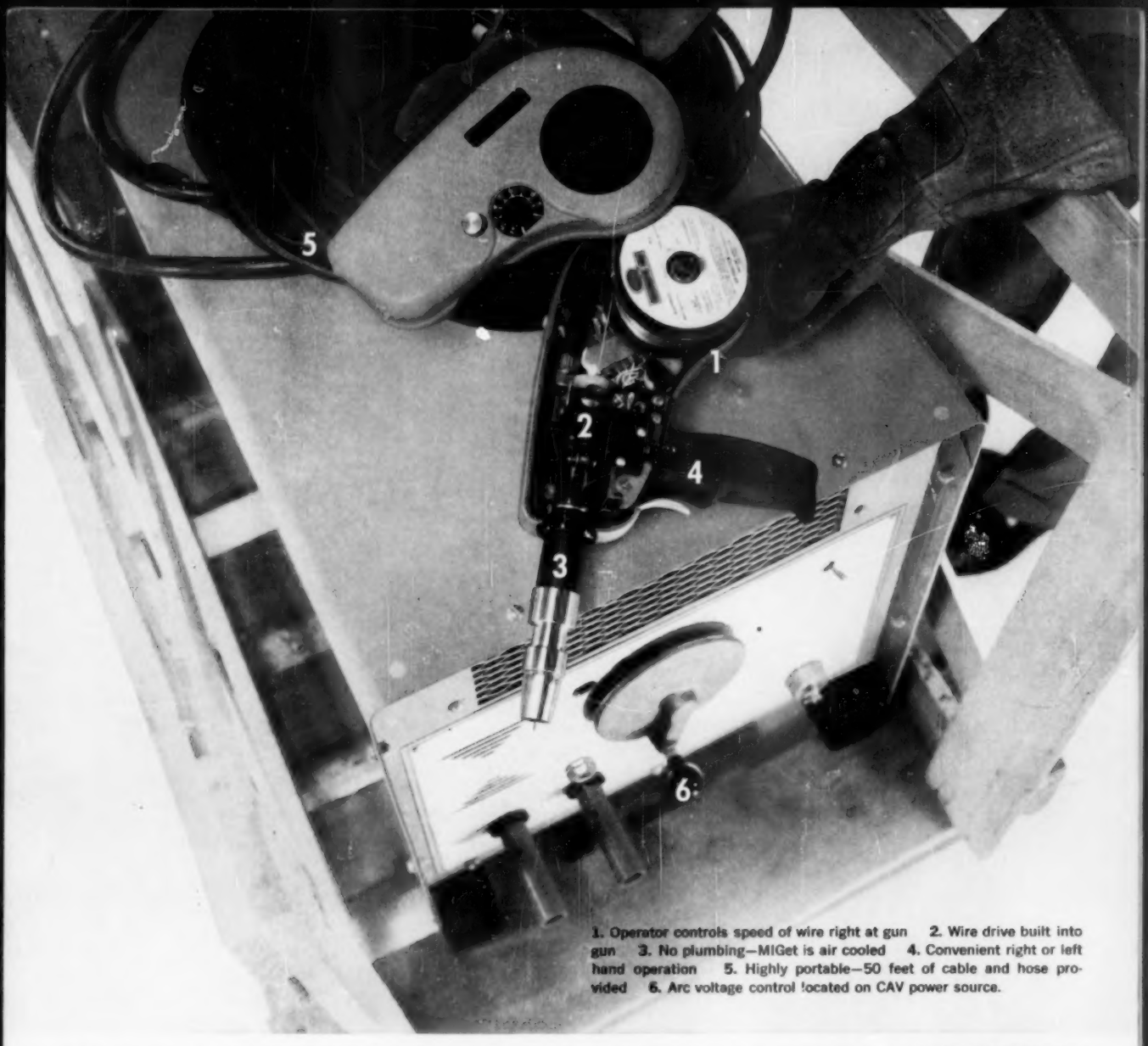

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